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Metrics for Objective Assessment of Surgical Skills Workshop

Developing Quantitative Measurements through Surgical Simulation

Sponsored by

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US Army Medical Research Materiel Command Telemedicine and Advanced Technology Research Center (TATRC)
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National Board of Medical Examiners (NBME)

Mountain Shadows Resort
Scottsdale, Arizona
9-10 July, 2001

Acknowledgement

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Foreword

The profound revolution in healthcare, from managed care to gene-based therapies to artificial organs to robotic surgery to virtual reality to microelectronic mechanical systems (MEMS) and nanotechnology, has disrupted the entire practice of medicine and surgery in an incredibly short period of time. It is no wonder that the public, which is becoming more educated through the media and the Internet, has come to question the competency of the practioners. In November, 1999, the Institute of Medicine completed its report "To Err Is Human: Building a Safer Health System". In this report, it was estimated that from 44,000 to 98,000 patients died due to medical errors. However, it was not so much single errors by an individual, but rather inherent weaknesses in the complex healthcare system itself that led inevitably to competent and well-intentioned healthcare providers' actions that resulted in errors. One of the significant shortfalls identified was that of education and training. It was also recommended that new technologies, such as simulation and objective assessment, are powerful instruments that could improve physician competence and the quality of patient care.

For over 50 years the aviation, aerospace, maritime, military, nuclear energy and other high risk professions have been using simulators for training difficult and demanding tasks. In so doing, these industries have reduced errors to nearly zero. Since 1955, examination on a flight simulator has been required by the aviation industry and military as a component for certification and annual re-certification. Although the simulation and objective assessment for medical and surgical procedures is in its infancy, there are some technologies and methodologies that have been proven to be effective.

However, there are a number of problems which must be addressed during this initial period of objective assessment with surgical simulators. First and foremost, there is no agreed upon set of definitions of terms, no classification of the tasks that are being used for training and evaluation, and no curriculum to accompany the training. Although numerous investigators have excellent systems for training and evaluation, there is no commonality that permits comparison of results. Finally, there are no studies relating the training and assessment methods with patient outcomes.

This workshop specifically addresses the above mention critical infrastructure issues that will permit the science of surgical education to move into an era of objective assessment of surgical skills. It is clear that this is just a first step, but the technology is maturing rapidly enough that the medical profession should be able to accomplish the same quality of safety as other industries in a much shorter timeframe. This workshop also acknowledges that surgical technical skills are but a portion of the overall development and assessment of competency; however by providing a stringently validated component of technical skills, the overall quality of competency should be raised to a level that significantly reduces surgical errors and thereby improves patient safety.

Metrics for Objective Assessment of Surgical Skills Workshop
Scottsdale, AZ
9-10 July, 2001

Executive Summary

On 9-10 July, 2001 the Metrics for Objective Assessment of Surgical Skills Workshop convened an international assemblage of subject matter experts in objective assessment of surgical technical skills and of representatives of relevant official bodies involved in surgical education, evaluation and certification. There have been recent advances in the educational science of objective assessment and the technology of medical modeling and simulation (with surrogate tissue, abstract objects or virtual reality (VR) systems) for training of technical skills. In addition, focus on identification and prevention of medical errors, the need for objective criteria for assessment of surgical skills and the increasing demand for accountability to the public has revealed that there is no infrastructure for the objective assessment of technical skills. Several investigators are validating many different systems for training and evaluation, using different tests, criteria, validation methods and even nomenclature. This workshop is an attempt to establish a standardization of nomenclature and assessment methodologies so the surgical education, training and evaluation community can communicate with a common language and have a common basis for comparing statistics from different centers. The results of this workshop are to be considered a first order approximation from the community of subject matter experts that can provide a "straw man" for future refinement.

Purpose: The purpose was to establish a consensus on a baseline set of metrics from which future education, training, evaluation and research in the technical aspect of surgical and procedural skills can be measured. These metrics are anticipated to be useful in the full spectrum of technical skills, from initial evaluation of applicants, to objective feedback during training, to on-going evaluation of performance, to criterion for certification and as such can provide an educational "tool kit" which surgical educators can utilize for their training programs.

Goals: The goals were: To identify the validated, relevant measurements for technical surgical skills, to evaluate the currently available systems that have been validated in peer-reviewed publications, and to propose a set of objective training and evaluation tools for technical surgical skills that can be utilized by surgical educators and surgical training program directors (or "program directors").

__Objectives__: The specific objectives were to derive: Definitions, taxonomy, analysis of current systems, functional components for a core curriculum, list of validated systems available for a core curriculum and identification of areas that require further research.

__Scope__: It should be stressed at the outset that the objective assessment of technical skills constitutes only one of the range of competencies needed by a medical/ surgical professionals, and cannot, by itself, be used for certification of ability to practice medicine/ surgery at any independent/ unsupervised level. Technical operative competence, though of crucial importance in surgery, is not enough and must be accompanied by other skills, e.g., cognitive, clinical and humanistic etc., to result in a complete competent, safe, effective and caring professional. It is fully acknowledged that the measurement tools herein derived are limited to the technical skills, and do not, cover these other equally important aspects of professional competence.

__Methodology__: The derivation of the data followed a modified Delphi methodology using the experts indicated above (Appendix 1). Consensus on definitions (Appendix 2,3) led to the establishment of a taxonomy of abilities, skills, tasks and procedures (Appendix 4) that comprise the lexicon of technical skills assessment; this is a first approximation which will require further vetting to become all inclusive. The criteria of validity (face, concurrent, construct, content, and predictive) and reliability (inter-rater and test-retest) were reviewed for the candidate systems that have been reported in the literature. Subsequent steps derived matrices that identified which of the currently validated objective assessment systems (Appendix 5) corresponded to the various abilities, skills, tasks and procedures, and which systems could be used for different levels of training and evaluation (basic, intermediate and advanced) (Appendix 6). Also presented was a definition of levels of overall competence (Appendix 7) which could be applicable to the demonstration of technical skills. This five-level hierarchy is: Novice, competent, proficient, expert and master.

__Results__. The results fall into five domains: Definitions, taxonomy, list of systems, levels for curriculum development and research opportunities (Appendix 8).

(a.) Definitions. Within the definitions process there was extensive discussion regarding the appropriateness of the term "abilities". It was recognized that there are numerous social, political and legal implications attached to the connotation of the term. However a large body of scientific literature with specific relevance for the assessment process decided the use of the term ability. The following are some of the essential definitions for objective assessment (Appendix 2):

Ability The natural state or condition of being capable; innate aptitude (prior to training) which an individual brings to a given task

Skill Acquired (by training) proficiency and execution in some art, craft, or the like

Task A piece of work to be done; a difficult or tedious undertaking usually incorporating multiple skills

Procedure A series of steps taken to accomplish an end

(b.) Taxonomy: Once the definitions were agreed upon, a classification (taxonomy) of the various types of abilities, skills, tasks and procedures was proposed based upon the measurements f objective assessment that have been reported in the medical literature on objective assessment. It is acknowledged that this is not a comprehensive list, since it does not include known measurements from non-medical literature that have not been validated by medical education researchers nor does it address the numerous procedures from the vast array of specialties and sub-specialties which have specific operations and procedures. In addition, the state-of-the-art in simulation technology permits the high fidelity simulation (whether real or virtual simulations) of only a few complete procedures. Nevertheless, the workshop has provided a rather comprehensive set of assessment tools for basic and intermediate surgical skills training.

(c.) Analysis of Current Systems. Initially, the Department of Defense (DoD) simulation program, which has a major medical modeling and simulation (MM&S) initiative by the US Army Medical Research and Material Command's Telemedicine and Advanced Technology Research Center (TATRC), was reviewed to understand how a single, integrated, large-scale effort in surgical simulation is managed. Subsequently, following a presentation of the validated systems for surgical skill education and training in the United States, Canada, Europe and Australasia, the component exercises of these systems were analyzed to see which exercises measured fundamental abilities, technical skills, complex tasks and full procedures (Appendix 5). It was evident that many of the existing systems measure the same or similar skills, and therefore can be expected to provide a basis for comparison of results. There were also a few measurements considered important, such as tissue handling, for which there were no exercises or tests. This provides an insight into areas for future research (Appendix 8). The vast majority of the tests are for skills and tasks, with only a few for fundamental abilities or for total procedures. The implications are that the large pool of scientific research on abilities for safety in the aviation, transportation, nuclear power, military and other fields need to be investigated for medical applications. Likewise, it was noted that there were few

complete surgical procedures that have been simulated, and those which do exist are not of high fidelity. Nevertheless it was felt that the science of simulating tissue from synthetic materials or in virtual reality will continue to rapidly advance and that within a decade or two it will be possible to have simulations of simple procedures that are extremely close to actual procedures. There are some early successes in anesthesiology and ultrasound (with a mannequin), endoscopy (colonoscopy, EGD, ENT Sinusoscopy) and interventional radiology (coronary angioplasty and stent placement) that were noted. It was repeatedly emphasized that the advantage of the simulators (especially virtual reality ones) is that as the simulators are being used for training, they are automatically objectively assessing performance, providing real-time feedback (proximate learning), continuous tracking of the student's improvement (the learning curve) and providing a quantative score for record. They can also be used for summative assessment of skills in surgical examination.

(d.) Curriculum development. The original objective of trying to provide a model core curriculum was a bit over ambitious. It is apparent that there are numerous methods that can be developed that would result in a valid core curriculum. Much discussion centered around 1) what the curriculum would be used for – initial evaluation of applicants, training of students, evaluation of progress and/or minimal performance standards to progress from one level of skills proficiency to another and ultimately as a basis for determining competence by proper authorities in certification. 2) for whom the curriculum was developed – the student, the program director, external reviewers or certification bodies and 3) who would decide the correct performance criterion – program directors, independent consensus workshops, training (e.g. Residency Review Committee) or certification bodies. Ultimately it was agreed that the first implementation would be structured for the program directors as an aid in training and performance evaluation of the students. This resulted in re-distribution of the skills, tasks and procedures into three levels – basic, intermediate and advanced – which the program directors could use and customize to the needs of their specific training programs. It was noted that the United Kingdom (as represented by the three countries of England, Ireland and Scotland) has examinations at three levels, which closely approximates the levels independently defined by this workshop. One of the limitations in trying to decide a core set of exercises for a "model curriculum" was that much of the current data has not been analyzed in such a way that enables different systems to be compared for reliability and validity, leaving the assumption that most were equally valid. This certainly points to a need, which is to develop a system to ensure comparability of results.

(d.) Research Opportunities. There were three distinct areas for research that were identified during the workshop. 1). A number of surgeons identified a need for a skill called "tissue handling". None of the systems measure such a skill. 2). There are only a few exercises which evaluate fundamental abilities; it is known that there are many such tests available in the non-medical arena and therefore these should be identified and validated for medical applications. 3). Comparison and integration of the various available exercises of the different systems into a single coherent "core curriculum". In addition, research in haptic abilities, as well as the fundamental abilities, are in their infancy and need more basic and applied research.

Future Directions. With the completion of this workshop report, it is proposed to conduct an Open Forum on Metrics for Objective Assessment of Surgical Skills. The purpose of this report will discuss and vet the original results of this workshop. A suggested time frame is contained in Appendix 9.

Metrics for Objective Assessment of Surgical Skills Workshop

Scottsdale, AZ

9-10 July, 2001

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Introduction (Satava).

The introduction provided a background on the purpose, goals, objectives and timelines for the conference. The goals (Table 1) were: 1.) to review currently available, peer-reviewed, surgical simulation systems for objective assessment of technical skills. 2.) To agree upon a set of definitions which would form the basis of discussion for the workshop, but to also establish an agreed upon lexicon of terms which all the current researchers in objective assessment would adhere to, and set a standard of definitions in objective assessment for future investigators. 3.) To develop a

taxonomy of the various metrics (abilities, skills, tasks and procedures) that comprise the "toolkit" which investigators can apply for objective assessment. The baseline reference toolkit was derived from the currently accepted and scientifically validated instruments which have been used for decades by researchers in behavioral psychology, ergonomics and human interface technology. 4.) To match the metrics in the taxonomy (from goal 3) to the current systems (from goal 1) to form a matrix or "toolkit of objective assessment tools" that could be made available to surgical educators and evaluators. 5.) To analyze the tools (from goal 4) and propose a generic "core curriculum" that can be reviewed by the international community of surgical educators to be implemented as a standard for the training and evaluation of surgical technical skills.

Table 1.   Goals of Workshop
Review current available systems
Definition of what is being measured
Develop a taxonomy for measurement
Match metrics to current systems
Develop a core curriculum

In evaluating the currently available systems of simulators, the participants were specifically directed to assessing the validity and reliability of the data presented. These were defined based upon definitions from a standard dictionary (New Webster's Dictionary of the English Language (Deluxe Encyclopedic Edition), Delaire Publishing, Inc, NYC;1981) and a dictionary specific to the behavioral psychology profession (Reber, AS   Dictionary of Psychology) (Appendix). The types of validity included face, content, construct, concurrent and predictive validity and the types of reliability included inter-rater and test-retest reliability (Table 2).

Finally, the timelines for the accomplishments of the workshop were delineated. This included the completion of the first draft, circulation among participants for review, completion of final draft, circulation among selected organizations, societies and regulatory bodies for comment, and for preparing the final report. In addition there were to be plans for a subsequent open forum to insure review and commentary by the international surgical education community as a whole, as well as an advisory board to insure continuation of the process of final report and Open Forum planning.

Table 2 Validity and Reliability

Validity

    Face

    Content

    Construct

    Concurrent

    Predictive

Reliability

    Test-retest

    Inter-rater

Military Medical Modeling and Simulation Program (Magee)

The US Army Medical Research and Material Command (USAMRMC) Telemedicine and Advanced Technology Research Center (TATRC) has several initiatives in surgical simulation as part of a broader Medical Modeling & Simulation (MM&S) portfolio. The main initiative in surgical simulation is a Congressionally Special Interest program with significant funding to implement simulation-based training for military medical requirements. TATRC' program scope is broader than simulation, with a vision to identify, explore, and demonstrate key technologies and biomedical principles required to overcome technology barriers that are both medically and militarily unique.

In April 1998, the General Accounting Office (GAO) reported, "Military medical personnel have almost no chance during peacetime to practice battlefield trauma care skills. As a result, physicians both within and outside the Department of Defense (DOD) believe that military medical personnel are not prepared to provide trauma care to the severely injured soldiers in wartime...." (GAO/NSIAD-98-75). With some of today's training methods disappearing, the challenge of providing both initial and sustainment training for almost *100,000* military medical personnel is becoming insurmountable. The "training gap" is huge, and impediments to training are mounting. This led the TATRC to identify needs for simulation (Table 3).

Thus the military sees a unique need to invest in these training modalities and are required to go forward regardless of civilian pursuits. The military has therefore already established a Medical Modeling and Simulation (MM&S) initiative and assumed a leadership role in surgical training. In

addition, the "To Err is Human" report (Kohn, Corrigan, Donaldson, Institute of Medicine. November, 1999) has focused the public's attention on the issue of medical errors and added a strong

Table 3. Identified needs for simulation

- Training should replicate combat specific wounds & battlefield environmental stressors.
- Civilian injuries are unlike war.
- Traditional "see one, do one, teach one" method is changing.
- There are increased restrictions on animal use for training.
- Cost to conduct mass casualty exercises is prohibitive.
- Health care payors are resistant to reimburse for training.
- There are risks from treatment by care providers-in-training.

civilian impetus for the TATRC program. Of all errors, those related to surgical procedures are the most dramatic and media-attention attractors. The Center for Patient Safety of the Agency for Healthcare Research and Quality has identified simulation technologies as an opportunity to increase patient safety through reduced errors by better surgical training.

Based upon these military requirements and overall public awareness of the medical errors problem, TATRC has developed an initial strategy which includes the following steps:

Table 4. Initial Strategy

Assess the landscape – perform a "Meta-Analysis"

Engage the experts – implement a 70-person "Integrated Research Team"

Converge the worlds- bring expertise of medicine & simulation together

Support the science – integrate existing congressional and other funding sources

Designate a "lead agency" - integrate efforts (TATRC has been designated)

Be a good partner - develop & honor professional business practices at all stages of the process

The thrust of TATRC's MM&S portfolio is an integrated, multi-level program (figure 1). It takes into consideration the multidisciplinary approach, involving users at all levels and in all agencies and bringing multiple sources of funding into a rich portfolio of projects that support the overall program

goals. This results in a very robust program that can leverage off many different disciplines to support MM&S in the many components, from partial task trainers to scenario based systems.
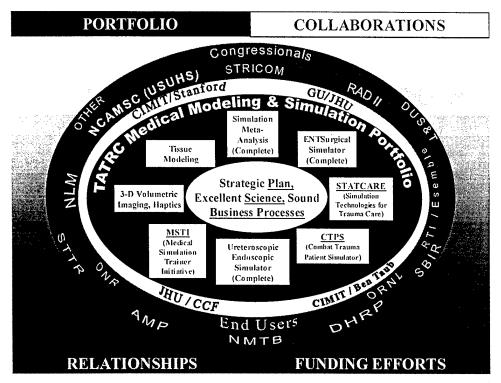
Figure 1 The TATRC Medical Modeling and Simulation Program

TATRC has categorized its portfolio of simulators into 4 categories to meet the military needs. They are: 1.) Personal computer (PC) based interactive multimedia, 2.) Digitally enhanced mannequins, 3.) Virtual workbenches, and 4.) Total immersion virtual reality. Each type of simulator has strengths and weaknesses, and the development of a core curriculum will need to take the strengths of each to form an optimal educational strategy.

The TATRC program will develop effective medical training simulators, by developing the fundamental science and enabling technologies that will permit learning on a simulator to be translated to actual patient care. Once this knowledge is available, developers can create application-specific learning modules, from first responder trauma triage through surgical part-task simulators.

A number of research challenges have been identified by TATRC during the initial Integrated Research Team (IRT) workshop on modeling and simulation.   These include (Table 5):

Table 5. Research Challenges

Real-time *in vivo* tissue property measurement and mathematical modeling

Tissue-tool interactions, haptics

Graphics and visualization

Learning systems

Validation and metrics

Open source architecture (Common Anatomical Modeling Language – CAML)

There are key components to the program management, including (Table 6):

Table 6.   Key Components

- Expand the consortia to address the core problems facing simulation.
- Constructively collaborate on various aspects of essential research.
- Support workshops in key areas of science.
- Demonstrate that simulator-based learning actually transfers to patient care, through validation studies and development of training metrics based upon simulator use.
- Identify sufficient funds to answer these needs within the next five years.

The program will be based upon robust validation methodology, with the first application being the Combat Trauma Patient Simulation (CTPS) System, a system of digitized mannequins – with Independent Test & Evaluation beginning July, 2001.

Oversight is conducted by refining the integrated, tech-based investment strategy for MM&S in direct support of Joint Warfighter Science & Technology Plan through the establishment of working groups for functional proponency, technology proponency and integration. The program management includes establishing Integrated Product Teams (IPT) for managing specific projects, such as Combat Trauma Patient Simulator (CTPS), Simulation Technologies for Advanced Trauma Care (STATCARE), and the Medical Simulation Trainer Initiative (MSTI) and then receiving, evaluating, responding to scientific proposals and workshop requests...and funding some of them. The USAMRMC Broad Agency Announcement Number 99-1 is an available avenue through which interested parties may submit research proposals.

In summary, the military is moving aggressively in developing and integrating simulation and objective assessment into the training of all combat medics, nurses, physicians and surgeons. Programs are identified, funded and provided oversight. Once appropriate progress has validated the systems, the military will be in position to be the leaders in simulation for medical technical skills training and evaluation.

Goal 1: REVIEW OF CURRENTLY AVAILABLE SYSTEMS

Master Surgeons and Surgical Proficiency (Cuschieri)

The issue of training surgeons revolves around determining surgical competence. There are two basic types of operative surgeons – the innately unbelievable operators (IUO) and the acquired master craftsman (AMC). The proficiency of these surgeons is demonstrated by their surgical operative proficiency, which is a combination of the efficiency and quality of their task performance (surgical operative proficiency = task efficiency x task quality). Performance can be in either an autonomous "subthalamic" mode or a cognitive "cortical" mode. In addition performance must take into account the learning curve, the rate at which a surgeon attains proficiency.

Surgical competence is achieved by selecting the right people and placing them in appropriate training/assessment programs which include the full range of competencies needed. Once attained, there is the need for both continued professional education and re-validation. However, this must be obtained using a new paradigm; no longer should there be so much audit with it's putative implications, rather it should be based upon quality performance to bring the surgeon's proficiency into a region which reduces risk and error into the "as low as reasonably possible" (ALARP) region. Some surgeons will immediately rise to a level of proficiency, the majority will remain in the "learning zone" for a longer time until proficiency is obtained, and a few will never attain a true level of proficiency (figure 2).

Current training in surgery spans the full spectrum, from selection of trainees based upon aptitude through clinical apprenticeship, using skills courses (including simulators) and training initiative lists. However, this traditional methodology is no longer sustainable; for example, only 20% of United Kingdom consultants currently supervise colon resections (Aitken, et all, 1999). An estimate of the order of magnitude of effort to raise the supervision of trainees from 30% to 70% supervision would require an additional 270 operating theater days in the United Kingdom at a minimal cost of £1.2 million pounds (£2million) in addition to the numerous extra teaching sessions.
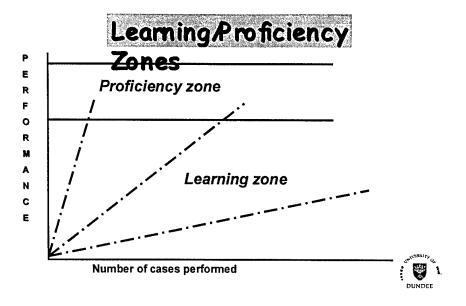
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Figure 2. Learning curves and levels of proficiency

It is imperative for academic surgeons to examine the different levels of competence in order to reach decisions about competence and proficiency, including abilities, skills and tasks. Abilities (innate attributes for surgery) include cognitive ability, personality traits and psychomotor ability. Although cognitive and personality traits are important for competence, technical skills revolve around psychomotor abilities. There are non-motor abilities (spatial and verbal) and motor abilities (control precision, two-hand coordination, hand-arm steadiness, eye-hand coordination speed, aiming and manual dexterity). Among spatial abilities, there are a number of sub classifications (visio-spatial, spatial visualization and spatial orientation), all of which correlate to surgical skills.

There are numerous factors which also must be taken into consideration. These include: 1.) adaptability (the extent to which a person is able to interact effectively and appropriately with his or her physical and social environment - *Aiken, 1994)*, which translated to the surgical skills arena implies the ability to acquire new skills. 2.) Perceptual processing of indirect images (The acquisition and processing of sensory information in order to see objects of indirect images; also guides an individual's action with respect to these objects) and perceptual speed (the ability to recognize similarities and differences quickly - *Schofield, 1972)*. 3.) Perceptual motor coordination (The ability to generate appropriate muscular commands so that our limbs reach position in space specified by our perceptual system, for example eye-hand co-ordination - *Eyesenck, 1994)*, 4.) Multi-limb coordination (The ability to co-ordinate the movements of a number of limbs simultaneously - *Fleishman, 1966)*. 5.) Aiming (The ability to quickly and precisely perform a series of movements

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requiring eye-hand co-ordination - *Fleishman, 1966*), 6.) Arm-hand steadiness (The ability to make precise arm-hand positioning movements where strength and speed are minimized; the critical factor being the steadiness with which such movements can be made - *Fleishman, 1966*) and 7.) Control precision (Common to tasks which require fine, highly controlled, but not over-controlled muscular adjustments, primarily where large muscle groups are involved).

During a consensus conference of master surgeons deliberating the importance of attributes which bear weight on the determination of competence, it was confirmed that cognitive factors and personality traits were of the highest importance, while dexterity was perceived only as important, and research output received much lower valuation (figure 3). However, when the evaluation group considered the relative impact of the various factors upon technical competence, innate dexterity was clearly the most important determinant, while both cognitive factors and personality traits were considered less important.

Finally, it is essential to bring into the equation the importance of the feedback which is given to the student during the training episodes, which enhances the acquisition of skills. Feedback can be concurrent (real time) or terminal (after completion). With concurrent (or "proximate learning"), the subject is made aware of the error and can immediately correct it, whereas with terminal, there is an external assessment of the performance.
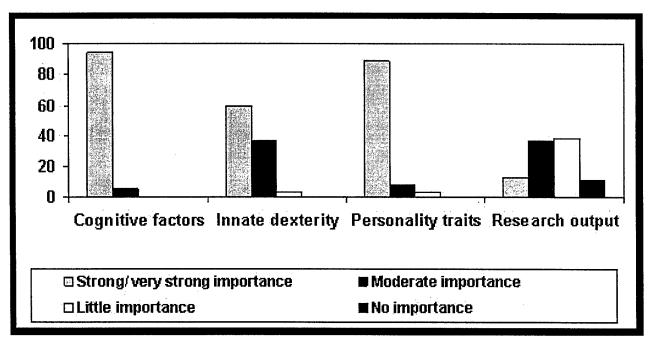
Figure 3 Consensus weighting of important factors
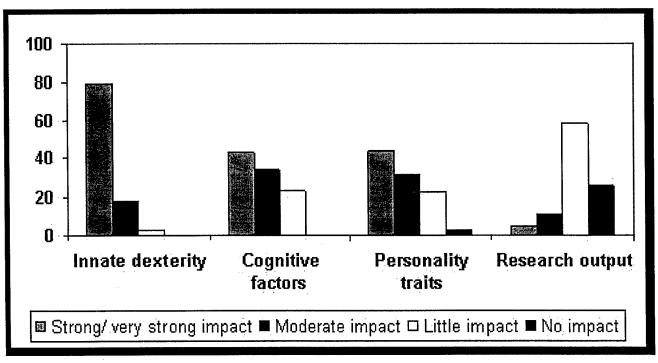
Figure 4   Impact of attributes on technical competence

Current Simulators

ADEPT   (Advanced Dundee Endoscopic Psychomotor Tester)

The ADEPT is a computer based, microprocessor controlled goniometer system with real time recording of x,y,z, position of active and passive instruments during bimanual dexterity manipulations. Plate exercises provide task targets and animal exercises provide surgical tasks. In addition the system has 3 infra-red cameras which locate/track reflective markers and tele-electromyographic components which transfer data to an on-line computer where the system software analyses motion patterns in 3-D. (figures 5,6). The system is a standardized, objective and reliable assessment method for endoscopic training because it discriminates between individuals in terms of their innate abilities to perform endoscopic tasks. The system has been assessed for reliability (Arch Surg, 1999) and has been shown to have test-retest reliability and to abolish inter-rater variability with internal consistency (coefficient alpha = 0.97 for inter-tasks and intra-tasks). Neither significant improvement with practice ($p > 0.1$ and correlation coefficient of 0.64 between runs) nor discriminative ability (significant difference between subjects = $p < 0.001$ and coefficient of variation = 68% for error) are evident.

Figure 5. ADEPT system with external view with student practicing
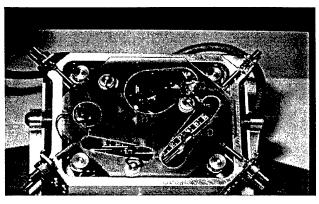
Figure 6.   ADEPT showing internal components

Face validity of ADEPT has been demonstrated (Surg Endosc, 1998) by using standard endoscopic instruments and video endoscopic system. The instrument movement has the same degrees of freedom as through an access port and the task plate reproduces generic endoscopic movement. In addition real surgical tasks can be used, e.g. knot tying and bowel anastomosis by replacing the plate with simulants or tissues. Concurrent validity (correlates with Crawford small part dexterity test - ESSR, Malmo 2000) has been established. Construct validity is proven because it differentiates between trainees and expert surgeons (EAES, Nice 2000) and predictive validity is demonstrated by the correlation between clinical competence amongst trainees, $r = 0.7$ (Am J Surg 1998).

Motion analysis is used to compare specific task performance between experts and trainees. ADEPT is able to establish what the experts do differently than trainees for a given task. Trainees simulate the experts' movements to improve task efficiency & quality. Task efficiency at knot tying reveals that experts average 60 seconds, while trainees average 120 sec ($p<0.0001$ by Mann-Whitney U-test), higher quality of knots with experts at 35% and trainee at 2% ($p<0.0005$ by Mann-Whitney U-test) and efficiency by angular velocity of the shoulder and elbow ($p<0.05$ by Mann-Whitney U-test) and reduction of abduction in range of motion (($p<0.05$ by Mann-Whitney U-test).
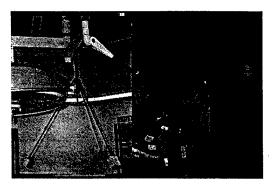
Figure 7   Motion analysis with reflectors and electromyographic electrodes.

Laparoscopy Cholecystectomy Simulator (Xitact,Inc)

The Laparoscopic Cholecystectomy Simulator (figure 8) by Xitact, Inc is a hybrid mannequin and virtual reality system with a mechanical haptic input component (using Stewart platforms and optical encoders) to provide force feedback and an image (figure 9) which is computer generated.
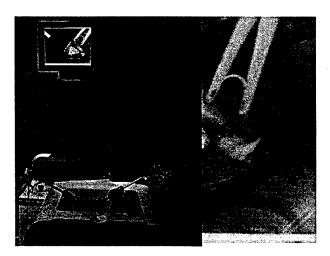
Figure 8 Xitact - external view   Figure 9 Xitact - computer image

The system is similar to many of the previous systems developed to train and evaluate the entire procedure of laparoscopic cholecystectomy. An objective assessment system is currently under development.

MISSIMU (Minimally Invasive Surgery Simulator) Dundee prototype

The European MISSIMU (Minimally Invasive Surgery Simulator), which has been developed by a European consortium, is also a hybrid simulator (figure 10) and represents the latest in mechatronic (combined mechanical and electronic) systems to provide the force feedback and a high

fidelity image (figure 11). The system has taken to a new level the fidelity in haptic input by devising a new mechatronic system (figure 12). The system has been devised to enable both the virtual reality system, as well as the opportunity to use simulants under the dome of the mechatronic device.
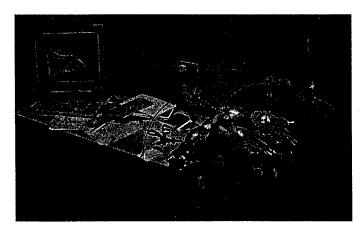
Figure 10. Two external views of the MISSIMU simulator

Figure 11. High fidelity image of the simulator

Figure 12 Haptic input device

The simulator continues undergoing evaluation with a comprehensive assessment system is continuing development. No validation data have been released.

Performance Levels

In reviewing the literature and convening the consensus of master surgeons, an ontology of performance levels can be constructed which reflects both the level of training and overall technical competence. The proposed levels, based upon those proposed by Stuart and Hubert Dreyfus, are: Novice, Competent, Proficient, Expert and Master (Appendix 7).

ADEPT – The Eindhoven E.A.E.S. Study (Jakimowicz)

The Advanced Dundee Endoscopic Psychomotor Tester (ADEPT) system was evaluated during the 9th International Congress of the European Association of Endoscopic Surgeons, 13-16 June, 2001.   There were 45 laparoscopic surgeons who participated, each receiving an instructional trial and a test trial (60 seconds per task). A post-test Visual Analogue Scale (VAS) questionnaire measuring attitude towards skills testing in general validation and performance on ADEPT was used. The outcomes denominators were hand-to-eye coordination, spatial perception, two-handed coordination, arm-hand steadiness and manual dexterity. The following hypotheses were tested.

Is performance on ADEPT reflecting innate psychomotor ability? (Scores will not improve with succeeding trials, there is no learning curve.)

Participants' scores on their test-run and true-run were compared. Patricipants did improve in total time needed for runs (test run mean time: 129 ± 54.4 seconds versus true run mean time: 100 ± 39.3 seconds). Also, the number of successful task performances on the true run was higher than on the test run (2.4 ± 1.3 versus 3.3 ± 1.0 successes). Innate ability is established as surgeons' score express high concordance between test-run and true-run, as 72.2% of participants expressed a true-run score within on distance from test-run. On paired samples Student's T-test, both time and score are significantly different ($p=0.001$ for both variables) indicative for some improvement/training effect. Thus the ADEPT is principally measuring fundamental psychomotor ability.

Are surgeons good estimators of their own performance on ADEPT ? (Scores on the ADEPT will correlate with their estimation of their ability on the VAS)

To quantify surgeons' estimate of their own performance, participants were asked the following question: "If I had to give myself a score for my overall performance on ADEPT, this score would be _____". This subjective perception of one's own performance was compared with the objective score on ADEPT. If surgeons are reliable estimators of their own performance, a linear relationship should be visible when both scores are plotted against each other. In order to do so, the authors computed a sum score parameter estimation (SUM) of objective individual performance on ADEPT.   This variable SUM takes the following into account: Successful tasks (0-5 points/run), total execution time <150 seconds (1 point), number of "perfect plate tasks" (1 point), and score on test run with at least one task successful (1 point). Thus, the maximum score of 10 could be achieved. SUM approaches the normal distribution and elements in SUM were in concordance. SUM was then plotted against subjective performance score. Mean VAS score for the test-run was

5.4 ($\pm$ 3.8) and mean VAS score for the true-run was 6.1($+$ 3.4). Mean score on SUM is (6.6 $\pm$ 1.64). In general, surgeons tend to modest in grading themselves for their performance on ADEPT. Nonetheless, the VAS score does not seem to be a reliable predictor of objective performance, since confidence intervals for scores of SUM all seem to overlap.

Do surgeons perceive the ADEPT to be a valid instrument in measuring laparoscopic skills ?

In general, there was no consensus on the validity of the system; the participants were equally divided in their evaluation.

Is ADEPT useful for validation of laparoscopic training techniques ?

The system actually assesses fundamental abilities. It would be necessary to use a simulator which tests skills, since skills have a learning curve (improve over time) and therefore can detect the improvement over time which would indicate the training value. The next protocol for the ADEPT evaluation will include the following (Table 7):

Table 7   Next protocol for the ADEPT

- Cohort of residents-in-training 2001 four regions (N=40)
- T0-T6-T12-T18-T24 measurements (months)
- One extra measurement following Basic Surgical Skills Course in Leiden, The Netherlands + instructed observer measurement of endoscopic performance on VAS
- Outcomes will be correlated to (previous) surgical and endoscopic experience
- Clinical supervisor will be asked once a year about abilities/progress
- Residents and Clinical Supervisor will not know outcomes during study

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Assessment Tools from the Imperial College, London (Darzi)

The Imperial College School of Medicine, London has developed and validated several objective measures of skill, applied to both virtual reality, inanimate and organic simulation. The tools developed are the Imperial College Surgical Assessment Device (ICSAD) and the Observer™ Pro Video Scoring System. In addition, validation has been performed upon the Minimally Invasive Surgery Trainer – Virtual Reality (MIST-VR) system by Mentice, Inc and the Royal College of Surgeons' Basic Surgical Skills curriculum using an Objective Structured Clinical Exam (OCSE) in conjunction with the Observer™.
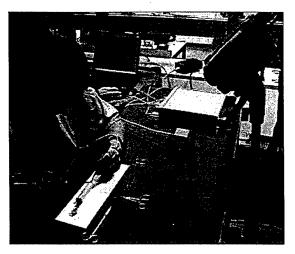
The Imperial College Surgical Assessment Device (ICSAD)

The ICSAD is a combination of a commercially available electromagnetic motion tracking system (Polhemus Inc, figure 13) which tracks instrument movement and compiles raw x,y,z data, using a Butterworth filter to smooth data, which is noise-gated and time stamped (figure14) using proprietary computer software developed in house at Imperial College. The custom software extrapolates this positional data into scores of dexterity and movement efficiency, namely the number of movements made by the hands, pathlength of hand/ instrument travel, and the time taken. As with all computer based systems, reliability is high since there is no "inter-observer" disagreement. Current limitations to motion analysis include: 1.) No measure of quality is determined, only quantitative data. 2.) Only dexterity is assessed, not other skills like visio-spatial, etc and 3.) Extensive outcome analysis research is necessary to validate long term outcomes.

ICSAD is a flexible, reliable assessment tool that has been used in laparoscopic simulation, open surgical simulation and within the operating theatre itself. It is not dependent on human analysis and interpretation, meaning that it is both truly objective and labor efficient. The ICSAD has been used to demonstrate the validity of many models and simulations to show both construct, concurrent and predictive validity, as well as reliability.. Examples of these studies are:

Construct validity

ICSAD has been shown to be a valid assessor and discriminator of experience in a number of laparoscopic and open surgical models, such as knot tying, suturing, bowel and vascular anastomosis. In all of these, experienced surgeons demonstrate greater movement efficiency. ICSAD has used path length as a measure of a surgeon's experience. There is an inverse relationship between the path length and experience; experienced surgeons have learned how to move directly (short path length) to perform procedures, but medical students or those with no laparoscopic surgery experience demonstrate
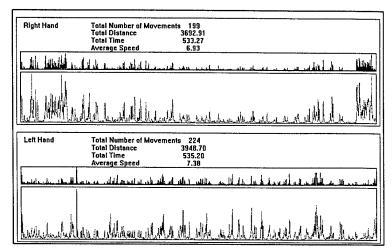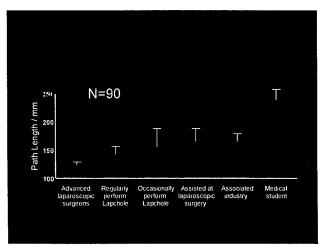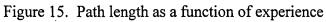
Figure 13 ISCAD Motion Tracking (Polhemus) Figure 14. Raw data of motion tracking, before filtering

long path lengths. (figure 15). In open surgical techniques, the teaching of mattress sutures reveals that senior house officers had more hand movements than experienced surgeons (figure 16). Thus there is a strong relationship with ISCAD between movements made and time taken, however this relationship is not fixed. When further correlation tests are applied in all these experiments, such as controlling for time, movements still correlate with experience / expertise / better outcomes. This is not the case when controlling for movements, which suggests that time taken is secondary to number of movements made.

Figure 15. Path length as a function of experience   Figure 16. Hand movement a function of experience

Concurrent validity

Performance on a number of models has been assessed using both ICSAD and other validated techniques, such as OSATS. Significant correlation between these two methodologies has been shown.

Predictive validity

Relative performance on a vascular model (anastomosis) as measured with ICSAD versus outcome (leakage across graft) has shown a significant relationship between skill and outcome (decreased leakage).

ISCAD has also been used to demonstrate the efficiency and impact of new technologies. For example, one study has shown the benefits of a 3D laparoscopic camera system with improved movement efficiency. Another has demonstrated the improved skill in knot tying and dissection inferred by a laparoscopic hand assist device.

The Observer™ system

The Observer™ is a video digitization system that is able to be programmed to quantify errors. The system has been developed by psychologists as a means of analyzing seemingly random human interactions in an objective manner. When applied to surgical simulation, quality of performance can be assessed without the need, or expense, of highly trained examiners. Different elements and surgical skills can be assessed, the focus dependent on what a particular study is concentrating on (eg: errors, order of op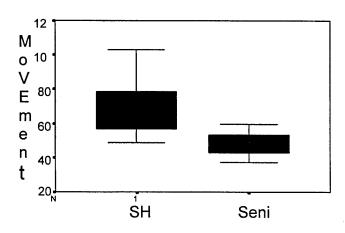erative steps etc). In addition, the system is computer based, so that performance which has been digitized can be analyzed retrospectively and anonymously. Again, this is a flexible analysis system that be applied to a spectrum of models and simulation environments, both laparoscopic, open and organic. The marriage of human and computer based analysis has also allowed very high inter examiner reliability to be demonstrated (typically over 0.85), lending greater confidence in both test task and assessment. For example, a study to compare and contrast performance during (porcine) cholecystectomy demonstrated an inter rater reliability between four observers of 0.89. Each operation was recorded and digitized (figure 17) and four independent surgeon observers scored each cholecystectomy. The results (Table 8) clearly demonstrate a very high level of correlation, indicating that Observer™ is a reliable tool for automatically assessing the performance of tasks that are recorded on video tape.

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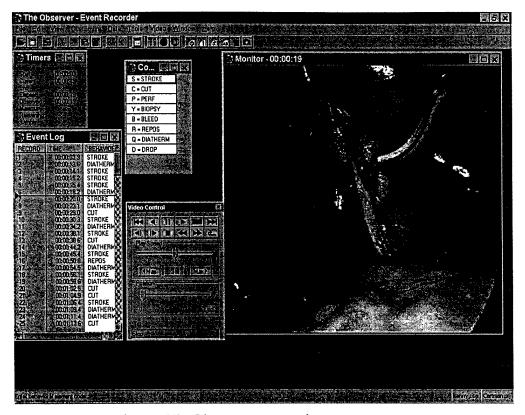
Figure 17   Observer automatic assessment system

CORRELATION COEFFICIENT	MEAN	STANDARD DEVIATION (SD)	Surgeon observer 1	Surgeon observer 2	Surgeon observer 3	Surgeon observer 4
OBSERVER1	107.5	32.3	1.0	0.849	0.986*	0.904*
OBSERVER2	119.3	31.9	0.849*	1.0	0.877*	0.813*
OBSERVER3	108.9	33.9	0.986*	0.877*	1.0	0.918*
OBSERVER4	120.5	44.4	0.904*	0.813*	0.918*	1.0

* Correlation significant at the 0.01 level

Table 8.   Results of correlation between the Observer system and the surgeon observers

MIST-VR (Minimally Invasive Surgery Trainer – Virtual Reality

The MIST-VR simulator is a personal computer (PC) based system which uses laparoscopic graspers and a computer generated image of abstract objects (figure 18). The tasks are based on the different skills needed for laparoscopic surgery, with movement efficiency, path length and errors recorded. However there is no tactile feedback. Studies at Imperial College have shown construct validity, i.e.: the system can differentiate correctly between levels of expertise. MIST has proved to be a

useful assessor of psychomotor skill. Further work has looked at the influence of environment on ability, for example, sleep deprived surgeons show greater movement inefficiency and errors than those fully rested (figure 19). Studies assessing the effects of alcohol on performance have revealed similar results.
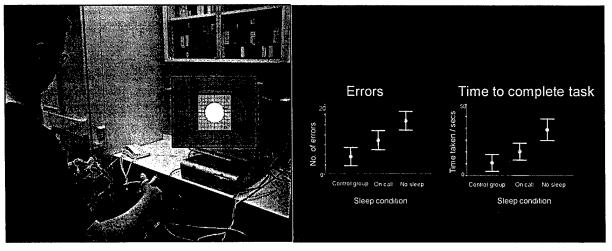
Figure 18 MIST-VR system   Figure 19 Effect of sleep deprivation on performance

Competence Day

A surgical skills assessment package for basic trainees has been developed and validated within the institution. The system is based on a six station OSCE format (figure 20), using synthetic and virtual
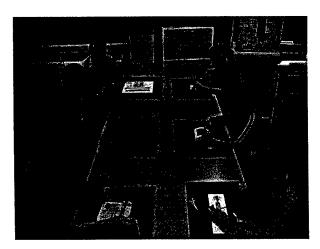
Figure 20 Students at 6 station OSCE

reality simulation, and the assessment processes outlined above. The stations have been chosen to reflect the important skills that trainees should have gained after two years of their residency. They are: knowledge of instruments and sutures, knot tying, suturing, excision of sebaceous cyst, closure of enterotomy, and basic laparoscopic navigation and manipulation. All stations have been validated with a

combination of two assessment tools (ICSAD, OSATS, Observer, MIST), and it is encouraging that strong correlations between these tools have been shown, increasing reliability and confidence in the process. Construct validity has been shown comparing junior trainee performance against senior trainees and consultants.

In summary, the Imperial College has implemented a comprehensive training and evaluation system which includes the traditional open surgery skills to the state-of-the-are in motion tracking and virtual reality. The systems can be used for assessing aptitude, training technical skills, evaluating performance and conducting research in variable conditions, such as under stress, etc.

Training Center Minimal Invasive Surgery University of Tuebingen (Buess)

The Univesity of Tuebingen has been conducting standardized training in surgical skills for over 12 years. The focus has been upon minimally invasive procedures, from laparoscopic surgery to Trans-anal Endoscopic Microsurgery (TEMS). Simulators have been designed which are mechanical phantoms (figure 21) as well as animal tissue parts mounted into moulds of the human torso, such as the artificial anus for TEMS simulation (figure 22).
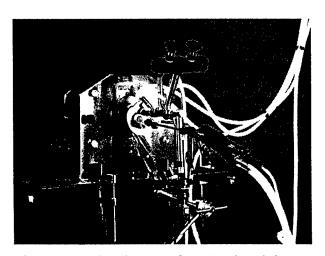
Figure 21. The phantom for TEMS training   Figure 22 Example of tissue based simulator

For laparoscopic surgery, the mechanical system (figure 23a) has been developed to provide the strengths of analysis of motion with computer based systems in evaluation and the realism of using actual animal tissue specimens (figure 23b) for high visual and tactile fidelity.

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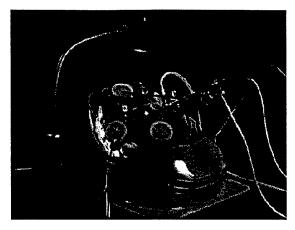
Figure 23a Laparoscopic trainer

Figure 23b Organ specimens in torso for trainer

An assessment of technical surgical skills has been performed in order to compare different methods of training with objective self-assessment tools that measure operative skills, observe the learning curve and eventually provide outcomes analysis that will allow for the setting of standards. The criterion used were: Precision (aiming accuracy), speed (time to completion), number of procedures, efficiency of movements and number of submovements. A structured scoring system was employed which used both objective measures from the instruments as well as subjective observer evaluation. In addition, an assessment of learning progress was performed on an abstract psychomotor analysis model with measurement of trajectories by ultrasound triangulation in a new, portable configuration (figure 24). The measured values are: time, x,y,z- coordinates, acceleration, submovements, detour-factor and error rate. In addition, a full visualization of the hand motion during a single trial can be created using trajectory analysis (figure 25).
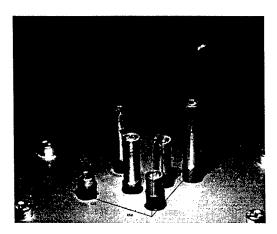
Figure 24 Multiple peg tracking task

Figure 25 Trajectory of motion with 20 target points touched

32

Analysis of the hand motion velocity as a function of time (figure 26) reveals that both beginner and expert surgeons have an initial rapid motion toward the target, but beginners waver back and forth trying to touch the target, while experts have initial velocity which deliberately slows down and quickly acquires the target.

Beginner (long overall duration, multiple velocity peaks)

Advanced user (one peak, then careful approach)
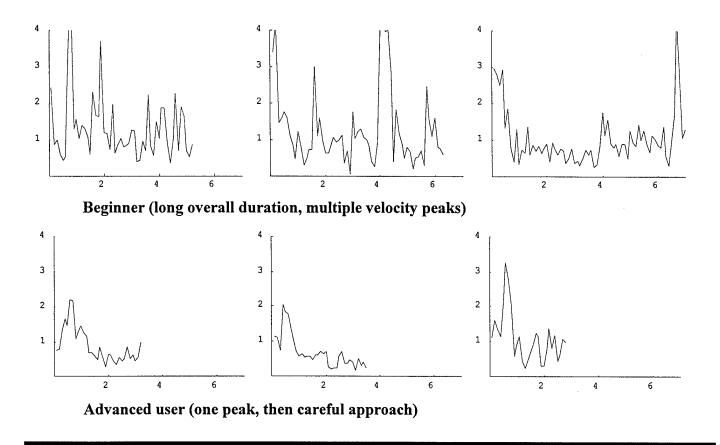
Figure 26. Results of motion tracking of beginners versus expert surgeons in multiple peg tracking task.

Comprehensive objective assessment of fundamental abilities for laparoscopic surgery. (Gallagher)

The introduction of laparoscopic surgery introduced new human factors and ergonomic problems. These problems include: Loss of 3-D vision (or more accurately binocularity), degraded tactile cues, degraded visual image, inadequate camera etiquette (e.g. camera rotation) and difficult to learn hand-eye co-ordination, especially the 'Fulcrum effect'.

There are a number of important factors that impact upon performance in minimally access surgery (MAS). These include cognitive factors (MAS specific knowledge) and technical factors (psychomotor ability, visio-spatial ability and perceptual ability). By definition, fundamental

psychometric abilities are fixed at birth or early childhood and show little or no learning effect (figure 27). These difficulties mean that the minimal access surgeon must perform surgery operating at the very edge of their perceptual, cognitive and psychomotor abilities. This also means that there is limited room for compensation during difficult procedures.
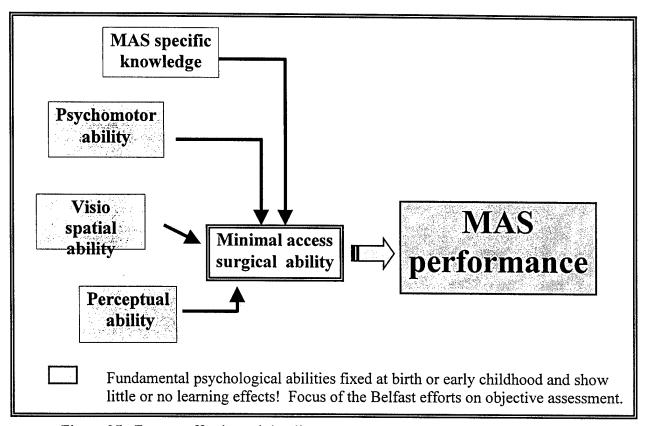
Figure 27. Factors affecting minimally access surgery performance

Psychometric abilities can be assessed using the Minimally Invasive Surgery Trainer – Virtual Reality (MIST-VR) (figure 28). This system (described above) is a psychomotor assessment device of six tasks of graded complexity which require two-handed manipulation of virtual spheres and cubes. To date, most objective research on MIST-VR has been as a training device, although it may be that MIST-VR is best utilized as an assessment device. The system uses the same endoscopic instruments as in the operating room (OR) requiring the two-handed manipulation of virtual objects and the use of diathermy on tasks 5 and 6. The limitations include no representation of virtual tissue and the absence of the sense of touch (haptics); however it has the advantage of being very reliable and affordable.

Initial studies focused upon a psychomotor ability validation of MIST-VR tasks as an assessment device with a *pure* psychomotor task (concurrent validity). The MIST-VR was correlated with a pursuit

tracking task and a compensatory tracking task (pure psychomotor ability). The pursuit tracking task requires participants to track a randomly moving target as closely as possible with a cross-hair; the compensatory tracking task requires the participants to use a joystick to attempt to keep the randomly moving target fixed to a central point. The results show a high level of correlation (figure 29) with r values of 0.792 or greater.

Figure 28 MIST – VR
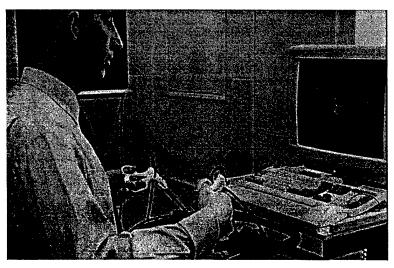
Factors correlated	Tracking scores		Time On Target	
	R-value	P-level	R-value	P-level
Pursuit with MIST VR	0.792	0.0222	0.857	0.0038
Compensatory with MIST VR	0.89	0.0009	0.89	0.0009

Figure 29   Results of pure psychomotor tracking validation task with MIST VR performance (n = 20)

The validity of the MIST-VR was conducted using the following four parameters: Time (the time subjects spent from when they started on the task until the time that they completed the last sequence of movements), Error (average error was measured as the number of errors per task segment.), Economy of Movement (assessed for the left and right instrument as the proportion of the distance travelled by the left (or right) each instrument tip (or working end) that has exceeded it's optimal distance) and Economy of Diathermy (the total burn time was used as a measure of economy of diathermy score for both tasks 5 and 6 only)

Construct validity was demonstrated between experienced surgeons (i.e., >50 MAS) versus junior surgeons (ie., <10 MAS).   The experienced surgeons performed MIST VR significantly faster with fewer errors, greater economy of instrument movement, greater economy of diathermy and greater consistency (i.e., lower SD's). MIST-VR distinguishes between surgeons of different levels of

experience, has a high test-re-test reliability r = 0.5 - 0.93, has high internal validity α = 0.89 - 0.98, has good construct validity and has good discriminative validity for surgeons of different levels of performance and laparoscopic novices performance. In addition the process of data collection is automated.

Perceptual ability is assessed using the P̲ic̲torial S̲urface O̲rientation (PicSOr) test battery (Cowie, *Perception, 1998*) which is designed to assess the ability to recover 3D information from 2D visual cues (figure 30). The test is specifically designed to provide only those cues (with shading and a rotating "arrow") which requires judgment of depth of field.
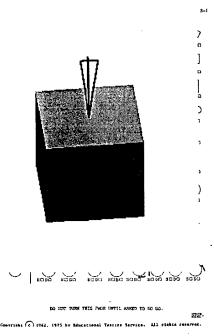
Figure 30 PicSOr Perceptual Assessment test   Figure 31 Visio-spatial Card Rotation test

Visio-spatial ability was assessed using the Manual for Kit of Factor-Referenced Cognitive Tests. (Ekstrom et al., 1976). The specific tests used were Card Rotation Test (spatial orientation), Cube Comparison Test (spatial orientation), Maze Tracing Test, Choosing a Path Test, Map Planning Test (spatial navigation), Form Board Test, Paper Folding Test and Surface Development Test. The three tests which correlated to a laparoscopic cutting task and to the MIST-VR were Card Rotation, Cube Comparison and Map Plan (figure 32).

All of the above tests correlate well with the MIST-VR and assess principally the fundamental abilities. Future tests need to determine if there are correlation with skills, such as Test 5 and Test 6 on MIST-VR. These tests involve the use of diathermy with the two handed manipulation of spheres and cubes, and therefore require multiple abilities and should reflect skills which can be learned.

Visio Spatial Test	Cutting task		MIST-VR Time		MIST-VR Error	
	r	p-level	r	p-level	r	p-level
Card Rotation	0.71	0.001	- 0.73	0.0005	- 0.67	0.002
Cube comparison	0.68	0.002	- 0.78	0.0001	- 0.69	0.002
Map Plan	0.45	n.s	- 0.7	0.0001	- 0.58	0.013

Figure 32. Correlation coefficients and their associated p-values between the visio spatial test scores and the three different measures of laparoscopic performance (n = 20).

The complete assessment of surgical competence and MAS performance is much more comprehensive than simple technical ability. Figure 33 demonstrates the many other components, such as experience, physiologic constraints (fatigue, stress, etc), equipment constraints, personality, teamwork, etc. that must be factored into the equation of competence and performance assessment.
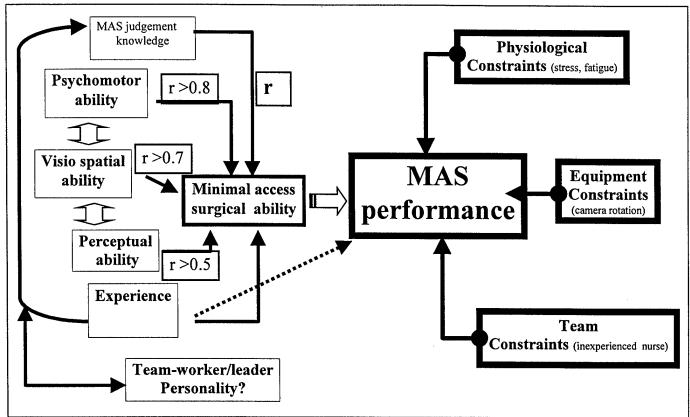
Figure 33   Multiple factors that impact upon MAS performance.

The conclusions are that objective assessment of skills for MAS is now possible. The factors demonstrated above which were believed to be related to MAS performance are strongly, and statistically, significantly. Virtual reality may be one of our most valuable tools in this enterprise to provide objective measures of fundamental abilities. Now it is necessary to establish norms for these measures with national (but preferably international) performance criterion levels for fundamental abilities for MAS. Lastly, and most importantly, it is necessary to determine if the psychometrics tests predict skills transference and OR performance. Evidence from other high skilled professions indicates that they will.

The Intercollegiate Basic Surgical Skills Course (Royal Australasian College of Surgeons) (Deane, Hamdorf)

The Royal Australasian College of Surgeons (RACS) conducts surgical training across Australia and New Zealand. The RACS training programs extend across the entire spectrum of training and include selection out of internship (PGY1), basic surgical training (BST) in PGY2,3 with

possible extension into PGY4,5, advanced surgical training (AST) for nine major specialties and continuing professional development.

The BST begins with selection and registration for training. There is a defined syllabus and compulsory distance learning program with text modules and interactive on-line resource units. There is the opportunity for a distance learning programme with text modules and interactive on-line resource units. For certain circumstances there is a mentoring programme. Skills courses include Basic Surgical Skills (BSS), Early Management of Severe Trauma (EMST – the RACS implementation of ATLS) and Care of the Critically Ill Surgical Patient (CCrISP). EMST began in 1988 by arrangement with the American College of Surgeons. CCrISP began in 2000 by arrangement with the Royal College of Surgeons of England. BSS is the intercollegiate Basic Surgical Skills course conducted by the Surgical Colleges in the United Kingdom and began in Australia and New Zealand in 1999 by arrangement with the Royal College of Surgeons of England. Each of these courses is conducted at multiple locations. BST evaluation involves both formative and summative assessments, including a clinical skills OSCE and a pre-determined standard must be reached to allow application for AST. The RACS is establishing collaborations with universities, state governments and health administrations, other professional organizations, and private industry to set in place the necessary facilities and resources which will be required for the future of laboratory-based skills training in Australia and New Zealand.

The Intercollegiate Basic Skills Course has been described (Hamdorf). The important components of the Course included a high tutor to participant ratio (1:2 to 1:3), fostering an air of stewardship and team approach, allowing an opportunity for reflection. The course is delivered at multiple sites with varying levels of technological backup throughout Australasia so is necessarily "low tech" in its approach.

The skills are taught on a 3 day course with open surgery (1.5 days), mulculoskeletal injuries (0.9 days) and minimal access surgery (1.0 days) and use operative techniques. The tasks performed are listed in Figure 34.

Open surgical skills are assessed with surrogate tissues or animal tissues. Knot tying and abdominal wound closure use synthetics (figure 35, 36), whereas excision of skin lesions and anastomosis are performed on animal parts (figure 37, 38).

- Gowning and gloving
- Handling instruments
- Tying knots
- Suturing
- Mesenteric dissection
- Anastomoses
  - End-end
  - End-side
- Transverse arteriotomy repair
- Longitudinal arteriotomy patch

- Wound Debridement
- Tendon repair
- Plastering technique
- MAS
  - Troubleshooting
  - Instrumentation
  - Manipulation tasks
  - Electrosurgery
- Safe Surgery/ Teamwork/ Attitude

Figure 34. Tasks in the Royal Australasian College of Surgeons Basic Surgical Skills Course

Participant performance is measured in two ways. Assessment was performed using a Likert scale, with 5 being no errors, 4 occasional errors which the participant corrected, 3 occasional errors uncorrected, 2 frequent errors and 1 unable to proceed without instructions. However it was stressed that the inter-rater reliability of this system had yet to be validated. Nevertheless the level of supervision allowed for an important component of formative assessment. In addition to this, the participants self-assess their performance in pre- and post-course measures of each of the skills/tasks/procedures using a 10 cm visual analogue scale (VAS).
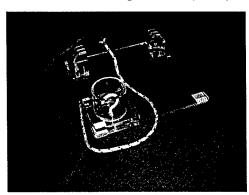
Figure 35 Knot tying

Figure 36. Abdominal wound closure
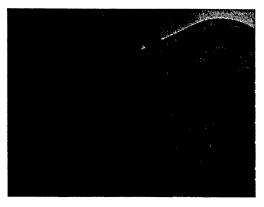
Figure 37 Excising skin lesion   Figure 38 End to side anastomosis

A total of 217 participants in 8 venues throughout Australia were tested with a tutor to participant ratio of 1:2 to 1:3. The administration of the training and evaluation is clearly very personnel intensive. Each of the tasks was assessed for the overall scores comparing the pre-test scores and post test scores. In the majority of the test there were high levels of correlation which indicated significant improvement during the course.
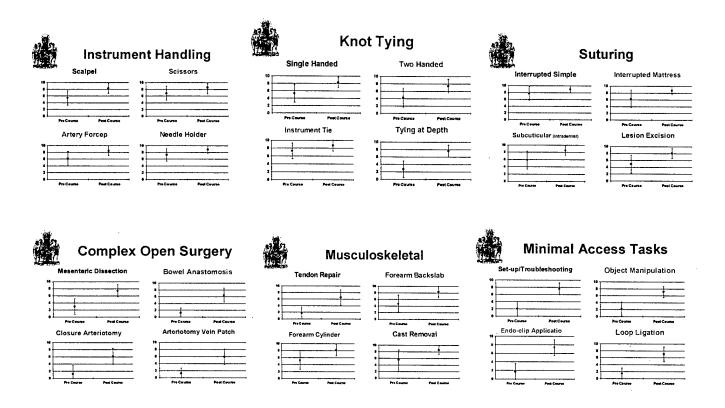
Figure 39 Individual correlations of the skills between pre-test and post-test evaluation

In spite of the validity of the BSS course, there are a number of issues which must be addressed. There needs to be a common language to share assessment evaluations. The tasks which are used represent a pragmatic approach, and more scientific exploration is needed. The courses are compulsory which has significant resource implication. Distant learning has raised the question of portability *vs* centre-driven courses. There must be curriculum linkage with the opportunity to practice learned skills.

The MISTELS Program: From Conception to Credentialing - (Fried)

For the training of young surgeons, operating room (OR) time is an expensive and limited resource. Training in laparoscopic surgery involves novel skills. Therefore learning opportunities in the OR can be optimized by having a basic level of skill and familiarity with instrumentation and skill in their use. These skills would best be acquired in a relaxed environment outside the OR. The approach taken is the McGill Inanimate Surgical Training and Evaluation for Laparoscopic Surgery (MISTELS).

The acquisition of the most basic laparoscopic skills requires 1.) Familiarity with the equipment and 2.) Learning basic technical skills of feel for tissue, traction-countertraction, ambidexterity, cutting, suturing, secure hemostasis, etc. This must be coupled with judgment and interpretation of anatomy and operative findings.

Education and assessment of surgical skills have evolved over time. The American Board of Surgery required intra-operative assessment of surgical skills as part of its certification process until 1952. The current skills assessment requires that residents maintain an operative log and perform a minimum number of specific surgical procedures. Final assessment of surgical skills during the residency program is by the In Training Evaluation Reports (ITERs). For certification in surgery the Royal College of Surgeons (Canada) and American Board of Surgery conduct objective examinations to assess clinical knowledge and judgement. There is no objective assessment of surgical technical skills. Scott, et al, compared scores on the American Board of Surgery In Training Exam (ABSITE) to performance in a skills lab and to intra-operative assessment of surgical skills. The conclusion was that there was no correlation between ABSITE scores and lab or intra-op assessment of surgical skills (Surgery 2000: 613-22). This raises the question "Is the current system of acquisition and evaluation of surgical skills adequate?"

There has been a recent move to develop objective training models to structure the acquisition and assessment of surgical skills in order to minimize time and expense while maximizing utilization of resources. One answer is to use inanimate training methodologies, which would provide training that is

easy to schedule, easily reproduced, provide objective measures and be cost effective. This need lead to the development of the McGill Inanimate System for Training and Evaluation of Laparoscopic Skills (MISTELS) Program. The program is based upon the following principles: 1). Tasks should be derived from the O.R. skills, 2.) The skills should be translated to operating room, 3.) Tasks should utilize actual surgical instruments and equipment, 4.) Performance must be objectively measured, 5.) The system should be inexpensive, portable and reproducible and 6.) Measurements should be sensitive enough to distinguish between different levels of competence.

In order to develop a reliable program it was necessary to develop exercises and the testing process. From these objective measuring tools were derived, which were subjected to reliability and validity studies. For the development of exercises, a panel of "experts" was convened to review videotapes of laparoscopic procedures and identify components of frequently performed procedures that could easily be learned and tested in an inanimate environment. In addition it was necessary to identify skills which were associated with a "learning curve". Finally it was important to use optical systems identical or "equivalent" to the laparoscopic system. The initial program began with an introductory video tape and 7 standardized exercises performed in an endoscopic trainer box which were scored for precision and speed.

Figure 40 The MISTEL system with portable and desktop images

The 7 tasks were: 1.) Pegboard transfer, 2.) Pattern cutting, 3.) Application of hemostatic clips, 4.) Placement of ligating loops, 5.) Placement and fixation of mesh over defect 6.) Placement of simple suture with intra-corporeal knot and 7.) Placement of a simple suture with an extra-corporeal knot

The pegboard transfer (figure 41) consists of lifting pegs from a pegboard with one hand, transferring them to the other hand and placement on another pegboard; then reversing the procedure.

The purpose is eye-hand coordination, bimanual dexterity and depth perception. Scoring is based upon dropped pegs for errors, and time to completion.

The pattern cutting (figure 42) requires the student to cut a circular pattern out of a 4" x 4" gauze suspended between alligator clips. The purpose is to use two hands to apply traction, expose best angle to cut, and to cut accurately. Scoring is by percent area cut outside of pre-marked line, and time to completion of task
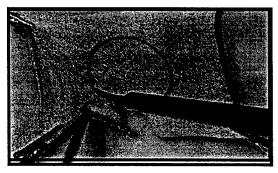
Figure 41 Pegboard transfer   Figure 42 Pattern cutting

The application of hemoclips (figure 43a) consists of placing hemostatic clips on a tubular structure at pre-marked positions, and cutting between the clips. The purpose is to replicate a similar procedure in surgery. Clips must be placed securely and accurately. Scoring is by accuracy of placement of clips, with penalty for insecure clips, measured against time.

The placement of ligating loops exercise (figure 44b) entails placement of a ligating loop (endoloop) at a marked position. The purpose is to replicate placement of a ligating loop during surgery e.g. appendectomy, requiring control of a tubular structure, accurate placement and secure seating of the knot. Scoring is accurate position, secure knot and time to completion.
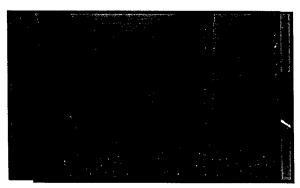
Figure 43a Application of hemoclip   Figure 43b Application of ligating loop

The placement and fixation of mesh over a defect (figure 44) requires the placement of a mesh patch over a defect. The purpose is to replicate placement of mesh as in hernia surgery, including secure fixation with accurately placed staples. Scoring is the percent of defect covered, security of fixation, number of staples required and time to complete task.
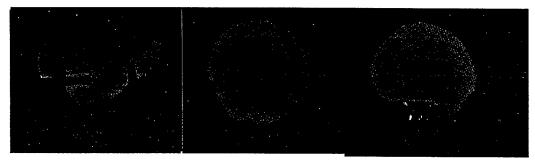
Figure 44. Placement and fixation of mesh over defect

The placement of a simple suture and securing it with an intra-corporeal and extra-corporeal knot (figure 45) is conducted by placing a simple suture through marks on a Penrose drain and securing of the knot with intra-corporeal or extra-corporeal technique. The purpose is to develop skill at introduction of a needle into a trocar, transfer of needle between needle holders, placement of suture, and knot tying. Scoring is by accuracy of position, security of knot, time to complete knot.
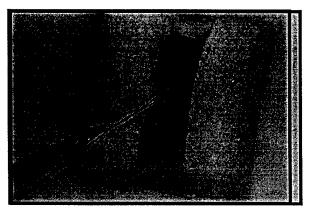
Figure 45 Placement of simple suture with intra-corporeal and extra-corporeal knot

First the program was tested with inter-rater reliability (n=16: ICC=0.991 with 95% CI: 0.973-0.997) and test-retest reliability (n=12: ICC= 0.889 with 95% CI: 0.628-0.968). Construct validity was performed on 149 volunteer academic and community surgeons, junior to chief resident and

laparoscopic fellows from a wide geographic distribution (< 15 medical schools in Canada and the U.S.) with a wide ethnic, gender and handedness diversity. Junior subjects (n=77) were PGY 1,2, and 3 and senior subjects were PGY 4,5, fellows and attending surgeons. The results clearly show improving scores with increased experience (figure 46) to prove construct validity.
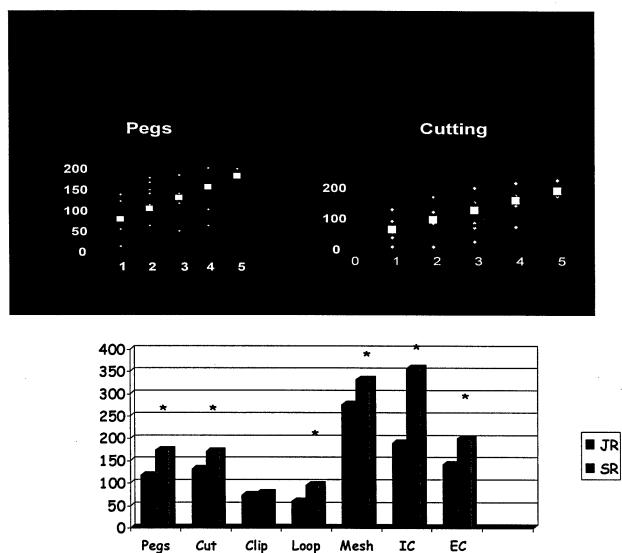
Figure 46 Construct validity showing increased proficiency with years of training

Concurrent validity evaluated the relationship between performance in an inanimate laparoscopic trainer in the MISTELS program and analogous tasks *in vivo* (figure 47). The experiment consisted of 12 residents who were evaluated using the inanimate *laparoscopic* trainer and then performed analogous skills in a live pig model. Correlation was done between *in vitro and in vivo* skills to determine the

effect of practice *in vitro* on performance *in vivo*, as tested in 6 of the 12 residents. All tasks, except the loop task, showed significant correlation to the p = 0.05 or better.
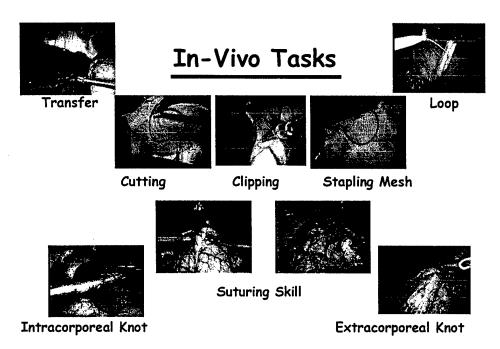
Figure 47 The *in-vivo* tasks corresponding to the inanimate tasks

	Pegs	Cut	Clip	Loop	Mesh	I/C	E/C	Total
r-value	0.57	0.59	0.42	0.16	0.35	0.56	0.68	0.70
p-value	0.003	0.002	0.04	NS	0.05	0.005	0.003	0.0001

Figure 48 Correlation between the inanimate and *in-vivo* tasks

Content validity was measured against subjective evaluation of resident's performance by attending surgeons during a clinical rotation. This ITER (In-training Evaluation Report) is a consensus of "expert" surgeons using a rating scale of Unsatisfactory, Borderline, Average or Superior. Fifty surgical residents who had their ITER in the same academic year as MISTELS testing had 4-6 independent evaluations of technical skill per resident per year. All evaluations were "satisfactory" or "superior". The percent "superior" evaluations versus MISTELS score was compared (figure 49) and demonstrated that the low and high scores are comparable.

In summary, the question of what is being measured appears to be a combination of innate ability and acquired skills. There is large variability at first testing, with decreased variance and better

performance with experience. Performance could be measured quantitatively. Evidence of validity is established by results that correlate with PGY of training, with seniors performing better than juniors and correlates to performance in live animals. In addition the scores reflect the overall evaluation of surgical skill by ITER. A longitudinal follow-up study shows each resident improves in MISTELS scores as he/she progresses through residency program. Finally the MISTELS program has a high inter-rater and test-retest reliability
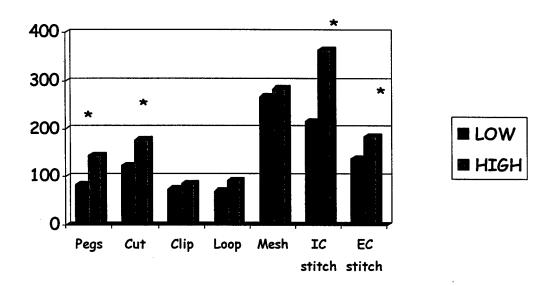
Figure 49 Content validity showing MISTEL SCORES versus low/high expert subjective scores

Iterative evaluations resulted in a few of the tasks being discarded. The application of hemoclips was not sensitive enough (it was too easy) and the placement and fixation of mesh over a defect did not add substantially to validity of the test (by multiple regression analysis) and was very expensive.

Overall, it can be concluded that the MISTELS system is inexpensive, easily reproduced, not labor intensive, portable, reliable and has been repeatedly validated.

The Objective Structured Assessment of Technical Skill (OSATS): Five years of research in the testing of technical skills in surgery (Regehr & Reznick)

Assessing procedural competence is one of the core expectations of a surgical training program. Traditionally, this assessment has been enacted through a preceptor's observation of a trainee's performance in the operating room. However, we can no longer rely on the patient context as the sole venue to evaluate (or teach) surgical procedures. There are many reasons for this, including: the ethical issues in using patients for these purposes, the high cost of the surgical minute,

the increasing intolerance of error, the difficulty in standardizing testing conditions and the difficulty in ensuring appropriate coverage of relevant procedures. This acknowledgement has led to a variety of efforts around the world to develop and research non-patient platforms for teaching and testing of procedural skills for surgical trainees.

Many of these efforts have involved the development of highly sophisticated technology-based simulators such as computer driven mannequins and virtual reality modules. However, at the University of Toronto Department of Surgery we were concerned that these "high tech" options were costly (both in development and in rollout), making it difficult for many schools to afford the hardware and software necessary to implement these solutions on a large scale. Further, the rapid advances in the technology almost guaranteed that by the time a model was ready for rollout, the technology on which it was based would be out of date rendering it sub-optimal relative to what was possible. And finally, we were not convinced from the perspective of educational theory that such highly sophisticated technological solutions were necessary for the development and evaluation of basic skills and procedural knowledge in surgery. Thus, when we began a systematic program of research into the teaching and testing of technical skills, the program of research was based on a philosophy of exploring the limits of less sophisticated, less expensive approaches to teaching and testing technical skills: the use of bench model simulations.

For the purposes of developing an appropriate evaluation tool to assess the technical skills of surgical residents, we adopted the format of the Objective Structured Clinical Examination (OSCE) as introduced by Harden. The OSCE is a multi-station examination in which participants are expected to perform a particular clinical task in a relatively short time period. The performance of each structured task is observed and marked either by a content expert (such as a clinical faculty member) or by an individual who is portraying the patient with whom the candidate interacts.

Starting in 1994, the surgical education research group at the University of Toronto began evaluating the feasibility, reliability and validity of a bench model version of the OSCE for evaluating the technical skills of general surgery residents. This evaluation tool came to be known as the Objective Structured Assessment of Technical Skill (OSATS). There have been several previous reports of individual studies evaluating the OSATS. This report compiles and summarizes these findings.

The OSATS is a multi-station "bell-ringer" examination in which segments of 6 to 8 surgical procedures are represented at a series of "stations" that are placed in a circuit around a room. For each procedure, the relevant anatomical structures are simulated by "bench models" that are

50

constructed from materials such as plastic, metal and fabric (Figure 50). A different candidate is present at each station and each is given instructions regarding the particular procedure that is to be performed at that station. All candidates simultaneously perform the appropriate segment of the procedure in a 15 minute period. Upon completion of the 15 minute period, candidates move to the next station and the process is repeated until all candidates have completed all stations. At each station, a knowledgeable operating room nurse is available to assist the candidate and a qualified surgeon observes and marks the candidates' performance.
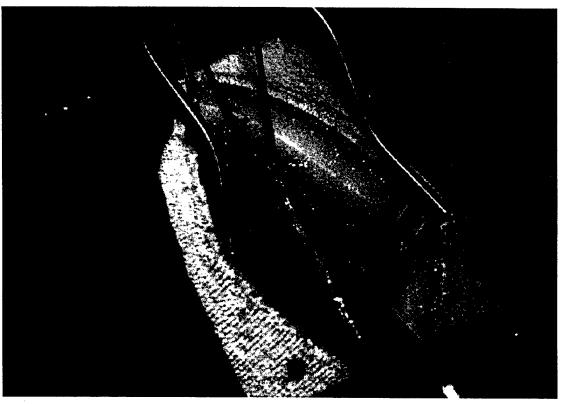
Figure 50. Sample of the simulated anatomical structure used for a typical OSATS station (embolectomy) built from foam, fabric, Penrose drain and colored liquid. Only the Penrose drain must be replaced for reuse of the model.

Examiners use two marking systems: a task-specific binary checklist and an operation-independent global rating scale. The task-specific binary checklist analyzes the elements of surgical maneuvers, enumerating each of the actions that are deemed relevant to the segment of the particular procedure being performed. For each action, the examiner indicates whether the candidate performed the action appropriately or not and the score on the checklist is the total proportion of items identified as having been performed correctly by the end of the 15-minute period. Because the task-specific

checklist is highly idiosyncratic to the particular procedure, a different checklist is created and validated by a group of content experts for each station. The global rating scale taps into the constructs of surgical performance, identifying several dimensions related to operative performance such as: respect for tissue, time and motion, instrument handling, knowledge of instruments, flow of operation, use of assistants, and knowledge of procedure. Each dimension is graded on a 5-point rating scale with points one, three and five anchored by explicit behavioral descriptors. A candidate's score on the station is the average of the marks on the seven dimensions expressed as a percentage of the total possible mark. Because the items on the global rating scale are intended to be operation independent, the same rating scale is used at each of the stations.

Admin	# Progs	# Cands	*PGY*	# Stns	# Exmrs
1994	1	20	1,3,5	6	12
1995	1	48	1-6	8	48
1996	2	53	2-5	8	54
1997	4	65	2-5	8	32
1998a	4	36	2-5	8	24
1998b	4	41	2-5	8	24

Table 9.   Details of the six administrations of the OSATS between 1994 and 1998.

•Excision of a skin lesion	•Chest-tube insertion	•Vascular anastomosis
•Abdominal wall closure	•Tracheostomy	•Insertion of J-tube
•Difficult skin closure	•Pyloroplasty	•Rectal anastomosis
•Control of IVC hemorrhage	•Hernia repair	•Ileostomy
•Embolectomy	•Insertion of a T-tube	•Choledocho-enterostomy
•Hand sewn small bowel anastomosis	•Stapled small bowel anastomosis	•Laparoscopic cholecystectomy

Table 10 List of stations used over the six administrations of the general surgery OSATS between 1994 and 1998.

Between 1994 and 1998, the OSATS was administered 6 times to a total of 263 general surgery residents from 12 programs across North America. Candidate training levels ranged from post-graduate year 1 (PGY1) to PGY6, with the majority of administrations including residents from

PGY2 to PGY5. A list of the administrations is presented in Table 9. A list of the stations developed and used in the context of these administrations is presented in Table 10.

Reliability refers to the precision of the scores generated by the examination. It functions as a form of signal-to-noise ratio where the signal is the individual's "true ability" and the noise is the error in measuring that true ability. A reliability of zero indicates that scores generated by the examination are simply noise (random error) and a reliability of one indicates that the scores generated by the examination is a complete signal (based on true ability). Reliability can be evaluated in several ways. It can, for example, assess the level of precision between two independent evaluators (inter-rater reliability). It can also assess the precision of measurement across many stations, inferred by the extent to which excellent candidates perform well across many similar tasks and poor candidates perform poorly across many similar tasks (internal consistency). Two forms of reliability have been assessed for the OSATS.

For each administration of the examination, the internal consistency of the examination across stations was calculated using Cronbach's alpha coefficient. The average inter-station alpha across the six iterations for the checklist scoring method was 0.65 (ranging from 0.33 to 0.79) and for the global rating method was 0.82 (ranging from 0.75 to 0.89).

In the 1994 and 1996 administrations, two examiners were placed at each station in order to assess the inter-rater reliability of the examination. To assess inter-rater reliability, the two examiners in each station were asked to mark the candidate independently. Each pair of examiners was specifically asked to avoid interacting with each other for the duration of the examination day, both during an examinee's performance (to avoid cross-examiner contamination of individual assessments) and between examinees (to avoid convergent drift in the use of the scales over the course of the examination). For each station, scores from the two examiners were compared using an intra-class correlation coefficient (ICC) with the examiner as a random factor in the model. In the 1994 administration the average inter-rater ICC across the six stations was 0.65 for the checklist scores and 0.70 for the global rating scores. For the 1996 administration, only a global rating was used by one of the examiners and the average inter-rater ICC across the eight stations was again 0.70 for the global rating scale.

Validity refers to the extent to which the test is measuring what one thinks it is measuring. Several methods have been used to establish the validity of the OSATS. First, for each iteration of the examination it was possible to assess the construct validity by comparing the scores of candidates at various levels of training experience. Table 11 presents the mean checklist and global scores by

year of training across the six administrations. For each administration, the simple linear Pearson's correlation was calculated between PGY level and the checklist and global rating scores. Across the six administrations the mean correlation of PGY status with checklist scores was 0.65 (ranging from 0.38 to 0.76) and with global rating scores was 0.70 (ranging from 0.46 to 0.84). Thus, training level is accounting for approximately 40% to 50% of the variance in checklist and global rating scores, suggesting quite reasonable construct validity for both measures.
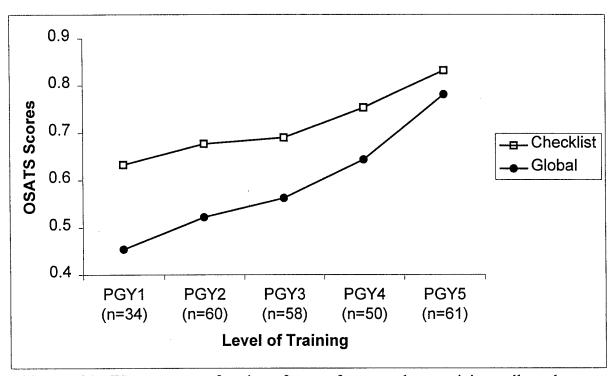
Table 11 OSATS scores as a function of year of post-graduate training collapsed across the six administrations of the examination between 1994 and 1998.

In addition to construct validity, several measures have been used to establish the concurrent validity of the examination scores. In 1994, the identical set of six stations was administered in both a bench model format and in a live animal format (using pigs). The Pearson's correlation between the bench and live versions of the examination (when disattenuated for the unreliability of the examination scores themselves) was 0.69 for the checklist scores and was 0.71 for the global rating scales, suggesting reasonable comparability between the bench model and live model versions of the examination.

In 1996, an additional measure of operative quality was created: an analysis of the final product generated by candidates at each station. For six of the eight stations, the final product of the

resident performance was collected and removed to a separate room. The final products for each station were evaluated by a pair of surgeons who were blinded to the resident's year of training and to the checklist and global scores obtained by the resident during the performance of the procedure. The quality of each final product was evaluated using four five-point rating scales that measured completeness, aesthetics, anticipated functionality and overall quality. Upon completion of the examination, each resident received a final product score which was the average of the six scores s/he had received for the six individual products evaluated. The Pearson's correlation of final product scores with the scores on the OSATS was 0.63 for the checklist scores and 0.74 for the global rating scores. This quite reasonable set of correlations provided evidence of concurrent validity both for the OSATS and for the final product measure, which itself has since been examined as a potential independent evaluation tool.

The first two measures of concurrent validity gave some credibility to the examination scores generated in the OSATS. In each case, however, the concurrent measures were associated with an extra-operative evaluation format. We were also interested in determining the extent to which scores on the OSATS related to performance in the clinical setting. However, no obvious measures of procedural competence in the clinical setting were available. The traditional method of evaluating procedural competence has been the in-training evaluation report (ITER), whereby clinical faculty supervisors, at the end of a clinical rotation, give a generalized impression of a resident's performance in a number of domains. While the ITER is based on multiple observations over an extended period of interaction, these scores are generally thought to have low reliability, limiting their value as an assessment tool and, for our purposes, a concurrent validity measure. In response to this concern a forced choice ranking procedure was developed in an effort to obtain a more useful measure of faculty opinion of residents' technical abilities. This procedure asked clinical supervisors to compare the operative skills of two residents directly rather than rating each resident independently. Through multiple paired comparisons across many pairs of residents and many faculty members, a rank order of residents was created. This rank order was structured to maximize the consistency of faculty opinion at the pairwise level. In 1996, a forced choice ranking of 18 PGY4 and PGY5 residents was created and compared to the ranking of those individuals on the OSATS. The Spearman rank order correlation between the clinical ranking and the OSATS ranking based on the checklist ratings was 0.72 and with the OSATS ranking based on the global ratings was 0.89, suggesting high concurrent validity for the checklist scores, the global scores and the forced choice rankings.

As described here, the OSATS was successfully administered as a general surgery examination for four consecutive years between 1994 and 1997. In the fourth year, the exam evaluated 65 residents from four different schools across Ontario and used examiners from all these schools with no change in the psychometric properties of the examination. In 1998 the examination was exported to two sites in the United States. For each of those administrations, the University of Toronto provided technical support, but the examination was largely coordinated at the local site. At both US sites, the administration was jointly supported by four separate institutions, which supplied both resident candidates and surgical faculty examiners for the examination. These two extramural experiences have strengthened our belief about the generalizability of our examination results and have confirmed the feasibility of a model of central examination preparation and peripheral delivery. In addition, the format has since been effectively adapted for obstetrics and gynecology in North America. Thus, its feasibility as an evaluation tool appears well established.

Further, the OSATS is now being used frequently at our own institution as an outcome measure for evaluating the effectiveness of teaching innovations, and has been adopted by researchers in the United Kingdom as a gold standard for evaluating new measurement instruments such as the motion analysis measures of the Imperial College Surgical Assessment Device (ICSAD). Adaptations of the OSATS are being used for evaluating surgeons who have been identified as having possible problems in the technical domain and is being explored as a testing platform for learning and performing new procedures in the context of clinical trials. Thus, it appears that the applicability of the OSATS is becoming increasingly widespread.

In summary, based on 5 years of research, our data indicate that we have been able to apply the OSCE format to the domain of surgical skills. We have developed a non-patient, lab-based platform for testing technical skills that demonstrates good reliability, established construct and concurrent validity, widespread feasibility, and demonstrable applicability. Further, we have effectively established this examination in the context of a bench model platform. The models we have used have varied in sophistication from very simplistic and inexpensive representations, to fairly realistic reproductions with reasonable anatomic fidelity. Data from our research group on simulation fidelity seem to be indicating that, for early surgical learners, low fidelity simulators work as well as do high fidelity simulators in teaching basic surgical manipulations. As of yet, we have not explored the utility of very costly approaches such as virtual reality simulations.

Rosser Minimally Invasive Skills and Suturing Program (Rosser)

The Rosser Minimally Invasive Skills and Suturing Program targets endoscopic suturing as the critical outcomes measure because it is the most difficult task to perform in the laparoscopic environment and requires the possession of advanced skill set to perform the task on a superior level. However, once endoscopic suturing is mastered, the surgeon has accomplished a tremendous advance when performing advanced minimally invasive procedures. Laparoscopic suturing requires accurate targeting, 2-D depth perception compensation, bimanual dexterity and two-handed choreography. Traditionally laparoscopic suturing is thought to require intensive and prolonged training, but this total program has been devised to train laparoscopic surgery in a short time. The program is devised to be very efficient (1.5or 2.5 day program) but it must be supervised (student/Instructor ratio is 4 to 1). Preparatory skill development has emphasis on non-dominant hand skill development. The program begins with didactic lectures and a compact disc- read only memory (CD-ROM) assisted curriculum with detailed deconstruction of the suturing process. This instruction is followed by the technical skills portion and finishes with an animal laboratory. To date a large data base with metric follow-up is currently available online to provide post course development evaluation. In addition a distant education program is available. After extensive evaluation, three primary technical skill drills have been determined to be effective teaching tools: The "cobra rope", "pea drop" and "triangle transfer". The cobra rope (figure 50) consists of two handed choreography, targeting and non-dominant hand development to instill proper suture directional manipulation. The pea drop (figure 51) requires 2-D depth perception compensation, non-dominant hand development and targeting (increasing accuracy when grasping tip of needle during suturing process). The triangle transfer (figure 52) develops non-dominant hand skills, 2-D depth perception, targeting to establish mechanics for atraumatic needle passage through tissue during the penetration phase of suturing
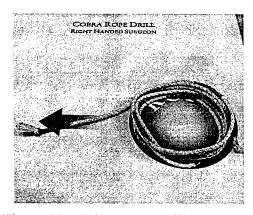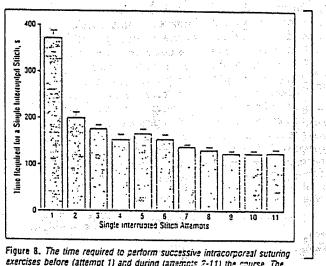
Figure 50   Cobra Rope Drill   Figure 51   Pea Drop Drill   Figure 52   Triangle Transfer Drill

To demonstrate validiitiy, 150 board eligible or board certified surgeon with extensive laparoscopic cholecystectomy experience were tested   Face validity was proven because the individual components of suturing were deconstructed in order to design the drills. Initially (T=0), 82% took longer than five minutes or could not complete an intracorporeal knot. After completion of the didactic and drills, it was demonstrated that preparatory drills had a high correlation with performance of suturing. The learning curve of both the three drills and the knot tying were comparable (figure 53). This demonstrated that outstanding suturing abilities can be achieved in a short period of time with this program.

Figure 8. The time required to perform successive intracorporeal suturing exercises before (attempt 1) and during (attempts 2-11) the course. The differences between attempts 1 and 2 and attempts 2 and 11 were significant (P<.001 for both. unpaired Student t test). Values are given as the mean±SEM.

Figure 53 The learning curve of the cobra rope drill and the intra-corporeal knot tying

For construct validity, dexterity drills and suturing were compared and demonstrated a significant difference between trained surgeons and pre-residency students (figure 54). The correlation coefficient between the suturing tasks and each of the drills was r= 0.051 and 0.053 with p<0.001.

Table 1. Dexterity Drills and Suturing Exercises, Trained Surgeons vs Residents*

| Dexterity Drills and Suturing Exercises | Trained Surgeons (n = 291) | All Residents (n = 99) | | Resident Subgroups† | | | | | |
| | | | | General Surgery Residents (n = 61) | | Gynecology Residents (n = 19) | | Preresidency Participants (n = 19) | |
		Time	P	Time	P	Time	P	Time	P
Rope pass drill	690 ± 10	676 ± 18	<.001	687 ± 23	<.001	630 ± 44	<.001	681 ± 42	<.001
Triangle transfer drill	445 ± 9	385 ± 16	<.005	389 ± 20	<.05	346 ± 37	<.05	411 ± 38	<.001
Old cup drop drill‡	890 ± 23 (n = 145)	1005 ± 43 (n = 43)	<.05	...	...§	...	...	...	...
New cup drop drill‡	1233 ± 30 (n = 146)	1371 ± 48 (n = 56)	<.05	...	...	...	...	...	...
Suturing exercises	1839 ± 38	1806 ± 67	<.001	1673 ± 84	<.001	1555 ± 156	<.001	2466 ± 19	<.001

*Time in seconds, mean ± SEM, required to complete 10 drills and suturing exercises by trained surgeons, residents, and subgroups of residents.
†Completion times of residents as a group and of 3 subgroups of residents are compared with those of trained surgeons by P values derived with unpaired, 2-tailed t tests.
‡In the old cup drop drill and the new cup drop drill, the numbers of participants are listed separately from the numbers in other types of drills and exercises.
§Ellipses indicate category of data not applicable.

Figure 54   Comparison of trained surgeons and students on dexterity drills and laparoscopic suturing

The effectiveness of CD-ROM multimedia tutorial in transferring cognitive knowledge for laparoscopic skill training was evaluated. (*American Journal of Surg. Vol 179(4), April 2000*).   Two hundred fifty one trained surgeons in four groups (US trained, US residents, Greek surgeons, US surgeons with didactic lectures) were given either the didactic lectures or the CD-ROM tutorial (with the same author for both methods of teaching) in order to compare the transfer of cognitive skills between the two methods. The results demonstrated that the CD-ROM is as effective as traditional didactic lecturing. The Greek surgeons showed depressed cognitive transfer but excellent skill transfer, perhaps due to the language differences. This observation implies that future tutorials need to be in the participants' first language; it also it indicates that a distant education curriculum may be possible. Therefore, a complete distant learning package (figure 55), based upon the CD-ROM multimedia approach validated above, along with the standard "box" trainer for the Rosser drills, has been created and is being implemented.

Figure 55 Distant learning package   Figure 56 The Gabriel-Rosser Inanimate Proctor (GRIP)

In order to include objective assessment of technical skills with automatic error detection, the Gabriel-Rosser Inanimate Proctor (GRIP) has been developed (figure 56). Whenever the student makes moves which are too uncontrolled, the instrument contacts the side of the platform and registers an error. Similar modifications to the cup drop (figure 57) and triangle transfer (figure 58) have been made.
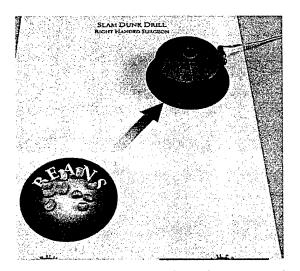
Figure 57 Automatic error detection on cup drop   Figure 58 Automatic error detection on triangle transfer.

A competitive program that serves as a focal point places skill development in the spotlight during conferences and meetings. Resident and trained surgeons alike are challenged to showcase their skills. This is a high profile recruitment opportunity to encourage the implementation of standardized skill development curriculums. Since 1996 over 800 surgeons have participated, including being featured at the annual meetings of the American College of Surgeons (ACS), the Society of American

Gastrointestinal Surgeons (SAGES) and the Society of Laparoscopic Surgeons (SLS). This competition

has been designated the "Top Gun" Laparoscopic Skills Shoot Out (figure 59), providing both an

opportunity of skills assessment with entertainment (edutainment).

Figure 59 The Top Gun competition and awards at the annual ACS meeting

In summary, the Rosser program is a comprehensive approach that is designed to establish the

advanced skill of intracorporeal suturing and anastomosis in a very short period of time. It is

applicable to novices and experienced surgeons alike. It has a standardized easily exportable format

with distant education capabilities. It has a large Internet accessible data base for initial and follow-

evaluation of progress.

Trauma Skills Training: Teaching ATLS with Simulators (Kaufmann)

The United States military has established the National Capital Area Medical Simulation Center

(NCAMSC) of the Uniformed Services University of the Health Sciences in Bethesda, MD. This Center

is one of the most comprehensive learning centers, which includes the three components of medical

education skills (cognitive, personal/communication and technical) into a single institution. There is a

computer laboratory area (for testing of cognitive skills in standard pedagogical format), a clinical

simulation area (examination rooms with video cameras for observation of clinical communication skills

while examining patient actors) for Objective Structured Clinical Exam (OCSE) of "standardized

patient" exercises and a surgical/virtual reality simulation area (with simulators for training and

evaluation of technical skills).

For learning technical skills, there is the dedicated surgical simulation laboratory, which includes the following simulators: Telepresence Surgery System (SRI, International), Anastomosis Simulator (Boston Dynamics, Inc), Limb Trauma Simulator (MuscluoGraphics, Inc), Surgical Workbench (Hand Immersive, Inc), CathSim & PreOp Simulators (Immersion Medical, Inc), UltraSim Ultrasound Simulator (MedSim, Inc), Patient Anesthesia Mannequins (Laerda, Inc., and MedSim Inc) (figure 60) and LapSim (Surgical Science, Inc) (figure 61). In addition, intra-mural research is improving upon the systems as well as developing new prototype simulators.

The NCAMSC is the only institution authorized to teach the Advanced Trauma and Life Support (ATLS) course by substituting simulators (both mannequin and VR technology) for cadavers or anesthetized animals in the technical skills practicum. This program is an experimental effort that attempts to decrease the number of animals that will need to be used for training of surgical skills. The goal of the ATLS course is to create a standardized protocol for the first hour of trauma patient care. This course serves as a common language for physicians from different countries working together. Internationally, approximately 25,000 physicians from 35 countries are trained and evaluated each year. Thus, the ATLS serves as an excellent first proof-of-concept for the evaluation of initiating simulation into the surgical educational process.
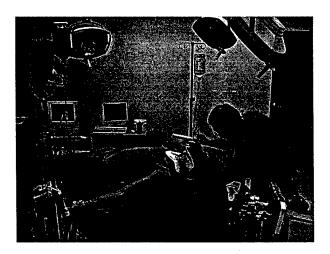
Figure 60 Patient Anesthesia Mannequin
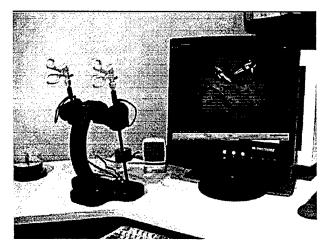
Figure 61 Virtual Reality simulator (LapSim)

Currently, the 4 technical skills in the practicum (diagnostic peritoneal lavage (DPL), pericardiocentesis, tube thoracostomy and surgical airway) are upon animals or cadavers. The NCAMSC has developed two simulators – the DPL (figure 62) and pericardiocentesis (figure 63).
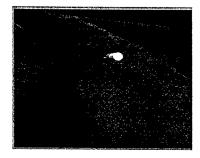
Figure 62 Diagnostic Peritoneal Lavage

Figure 63 Pericardiocentesis

The Center Integration of Medicine and Innovative Therapy (CIMIT^{TM}) is a non-profit consortium of world-leading academic and research institutions founded by Partners Healthcare System, Massachusetts General Hospital (MGH), Brigham and Women's Hospital, Massachusetts Institute of Technology, and Draper Laboratory). CIMIT is partnering with NCAMSC in developing a chest tube simulator and a surgical airway simulator is under development in collaboration with the Cleveland Clinic Research Center. In a preliminary assessment, 9 participants (6 surgery residents and 3 surgical staff) who had previously taken ATLS, participated in the ATLS course using the simulators instead of animals for the skills practicum. The survey (Likert scale) revealed that 7 believed simulation was as good or better (3 better, 4 as good) and two thought the simulators to be not as good. Further studies are designed to evaluate the validity. There is excellent face validity, since the images (see above) very closely resemble the patient encounter. These simulators teach and test the identification of correct site, angle, depth, and sequence for needle insertion tasks and can be generalized to other (Seldinger) needle-based procedures. While a bit more complex, the chest tube and surgical airway simulators will be able to be incorporated into the ATLS format.

Endoscopic Sinus Surgery Simulator (ES3) (Sinanan)

The Endoscopic Sinus Surgery Simulator (ES3) is a complete surgical simulator (figure 64) for otolaryngological sinusoscopy surgery. It is comprised of: 1.) An Immersion 6 degree of freedom (DOF) sinusscope (external) and operative instrument (internal, within a mannequin head) (figure 65) , 2.) 3-D segmented surface models from Visible Human Dataset with surface textures for left and right nasal sinuses (figures 66, 67, 68) , 3.) Haptic system control and 4.) Voice audio feedback and simulated heartbeat.
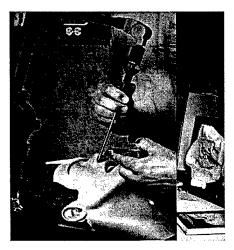
Figure 64 ES3 simulator evaluation Figure 65. ES3 mannequin   Figure 66 Abstract tasks
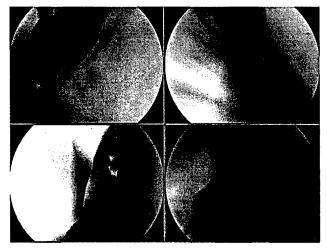
Figure 67 Sinus anatomy with overlay of guides   Figure 68 High fidelity of sinus anatomy

The curriculum is comprised of fundamental skills which are presented as the subtasks of navigation, injection and dissection. Metrics are: 1.) Time to subtask and overall task completion time, 2.) Accuracy (computed score), 3.) Errors and 4.) Position tracking from frame to frame. There are three levels – novice, intermediate and advanced. In the novice and intermediate modes, there are training aids of 3-D graphic overlays (circular hoops for desired endoscopic trajectory, bulls eye targets for injection sites and text labels). The training is taken through the levels of increasing difficulty. The novice level (abstract geometry + training aids) (figure 66) is designed for task practice, tool familiarization (needles, various cutting forceps, sickle knife, suction, microdebrider), and eye-hand coordination (geometry, hoops, bulls eye targets). The intermediate level (anatomically accurate + training aids) (figure 67) trains and assesses guided navigation (e.g. optimal trajectory), anatomy and guided injection. In the

advanced level (anatomically accurate) the focus is on integration of skills into procedures. There is haptic and audio feedback but no guides and the anatomy has augmented tasks, such as polyps. By having increasing difficulty and training aids, it is possible to "shape behavior" to perform tasks correctly. Evaluation was performed on three groups: 1.) Nonphysicians – 12 engineers (novice and intermediate models only), 2.) Non-ENT physicians – 8 (novice to advanced) and 3.) ENT surgeons (novice to advanced) comprised of 4 staff ENT surgeons and 8 resident trainees. The metrics were efficiency (time-to-subtask and overall task completion), trajectory path analysis, accuracy (measure of fidelity to assigned goals of procedure or task to meet an established criterion) and error (negative measure, proportional to clinical significance). The scores included *overall score* (composite value); *accuracy* (of eye-hand coordination; visio-spatial integration and anatomic knowledge (advanced model)); *hazard score* (for anatomic knowledge and visio-spatial integration); *sphere path score* (for efficiency of movement, eye-hand coordination (novice and intermediate) *and integration of task to anatomy* (advanced). Face and construct validity were demonstrated (figure 69) with correlation with experience of the residents and faculty.

	score	ESS perf	years_tr	age	trialtime
score	1				
ESS performed	.526	1			
years_training	.38	.923	1		
age	.236	.662	.713	1	
trialtime	-.966	-.652	-.514	-.33	1

Note: 1 case deleted with missing values.

Figure 69. Face and construct validity with correlation values

Motion analysis was also performed. It is clear by the trajectories (figure 70) that complete random motion of the novice consolidated to a tighter knot, followed by very deliberate motions in specific areas by the experienced surgeon.
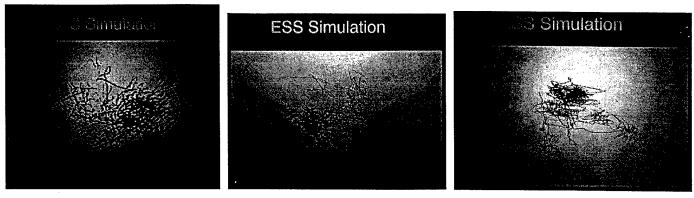
Figure 70   Motion trajectories of novice, trainee and experienced surgeons.

The advanced level provides a training and evaluation system for senior residents and surgeons. There is a direct effect of receiving training on the simulator with the ratings of participants (figure 71). Those with no simulator training performed worse than those with high ratings on the simulator, with the experienced surgeons performing best of all. This indicates that the ES3 simulator has both content and concurrent validity. There needs to be validation of predictive validity, by comparing simulator performance to OR performance.

- 1.   Injection
- 2.   Orientation of video image
- 3.   Image-task alignment
- 4.   Proper depth of image for task
- 5.   Tool-tool dexterity
- 6.   Tissue respect
- 7.   Tool selection
- 8.   Uncinectomy
- 9.   Anterior ethmoidectomy
- 10.   Maxillary antrostomy
- 11.   Tool manipulation
- 12.   Surgical confidence
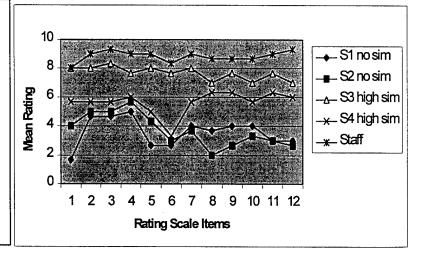
Figure 71 Advanced Level – effect of training on simulation.

The conclusion is that the ES3 simulator provides a valuable training and evaluation tool. The metrics logically derive from the nature of the simulator, which incorporates measures of efficiency, accuracy, and error. There is evidence of face, construct and content validity in that performances correlates with prior experience, training, handedness, exposure to similar task. The simulator has an embedded training curriculum to standardize the baseline knowledge. The initial orientation from

66

experts in the procedure was refined by subject survey and performance assessment. It remains necessary to validate objective measure of clinical performance.

The Holy Grail of Surgical Simulation: Teaching & Assessing Technical Judgment (Heinrichs)

A different approach to training and evaluation of surgical skills harkens back to ancient times. In 500 BC, the Hindu physician Sushruta. (Veith & Zimmerman, 1990) defined the eight (a ninth is added in modern surgery) basic tissue manipulations of all of surgery. They are:

• *Probing* – Exploration of a structure by visualization and/or palpation, including blunt dissection

• *Aspiration/Injection* – Penetration into a structure for removal or introduction of fluid

• *Incision* – Opening into structures & spaces by cutting

• *Evacuation* – Emptying of an anatomic space, or cavity

• *Scaraification* – Purposeful injury of tissues

• *Extraction* – Removal of a part from its anatomic site

• *Excision* – Complete removal of a structure by cutting

• *Closure* – Binding together, or apposition of surfaces

• *Implant- /Transplantation* – Introduction of a medical device or organ

Interactions of instruments with tissues are the fundamental deformations to be modeled in physics-based simulators. Instruction frames provide structured information in a computer instruction device that defines specific manipulations, each with a specific instruments and descriptions of their actions. Each tissue manipulation has various approaches using different surgical tools. Four levels of evaluation of manipulations are proposed – *approach to manipulation, execution of manipulation, consequence of the manipulation, and exercise of safety precaution during the manipulation.* Within each of these levels, three or more queries are proposed to define the metrics for training and evaluation.

Level ONE: *Approach to manipulations.* Examples of queries are:

Was an appropriate instrument selected for the incision task?

Was the appropriate site chosen to make the incision?

Was the site stabilized appropriately before making the incision?

Level TWO: *Execution of manipulations*

Was an appropriate angle of approach used?

Was the length of the incision appropriate for the immediate need

Did the initial instructions meet the exposure requirements for the entire procedure?

67

Level THREE: *Consequence of interventions*

Did the instructions of actions contribute to overall efficiency?

(1-sub-optimaL, 2- marginal, 3-optimal, 4-exuberant, 5-excessive

Level FOUR: *Exercise of Safety Pre-cautions during interventions*

Was the manipulation executed without risk of denuded tissue?

(1-clumsy, 2-marginal, 3-satisfactory, 4-conservative, 5-ineffective)
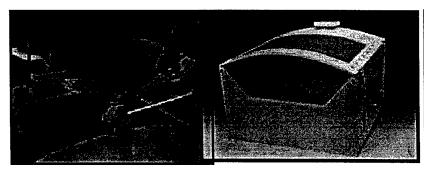
With this classification there are a possible (9 manipulations x 4 levels x 3 queries =) 108 variables available for assessment.

The conclusions are that tissue manipulations are the fundamental 'building blocks' for all of surgery. Generic surgical procedures can be constructed from standard choreography of these manipulations; however patient-specific procedures require custom choreography of manipulations. Technical judgment is required for competence in performing manipulations and their choreography and these are subject to objective assessment. The manipulations can be classified into 4 levels of assessment – approach, execution, consequence, and exercise of safety precautions.

A hystero-resectoscoe being developed by Heinrichs and colleagues at the Stanford/NASA Biocomputation Center and Immersion Medical incorporates these fundamental manipulations.

LTS2000 Laparoscopic Training Simulator and Objective Scoring System (Hasson)

Learning the visual-motor skills that are essential to performing video-assisted surgery is best achieved through practicing on an accentuated physical simulator. The haptics or force-feedback technology of today's virtual simulators, while promising, is not currently robust enough to provide the same degree of training. The LTS2000 (laparoscopy training simulator) (figure 72) was developed to fulfill the need for both hand-eye-video coordination and procedural skills in a cost-effective fashion.
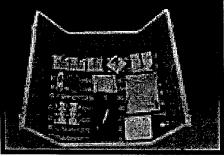
Figure 72. The LTS2000 Laparoscopic Training Simulator, external and internal views

Eleven exercises were designed to train skills such as delicate manipulations, circular motions, ductal cannulation, suturing and knot tying. Other exercises were designed to train procedure-specific skills such as cyst-removal, morcellation, and dissection. The LTS2000 exercises were designed to train three types of laparoscopic skills: Coordination, suturing & knot-tying and procedure-specific skills.

The tasks objectives for the coordination skills are:

1. Spatial perception and orientation.
2. Hand-eye coordination using the dominant and non-dominant hands separately.
3. Hand-eye coordination using the dominant and non-dominant hands together.
4. Appreciation of fine tactile sensations.
5. Ability to work under mirror image conditions or reversed hand-eye axis.

These objectives are tested by a pegboard and posts model (with bead placement on the pegboard and rings on posts), 3D-2D translation (by passage of a probe through a virtual cube to translate depth cues to color codes) and duct cannulation (by passage of a pipe cleaner through a duct and retrieval from the opposite side).

The task objectives for the suturing and knot-tying skills are:

1. Placement of interrupted and continuous suture.
2. Suture ligation of ductal structures using sliding loops.
3. Performing sliding loop and square extra-corporeal knots.
4. Executing instrument based squared intracorporeal knots.
5. Securing the first and last stitches of a continuous suture with stable knots.
6. Building and tying preformed knots such as the rolling hitch knot.

These objectives are tested by an external post model (forming a Roeder loop extra-corporeal knot), silastic tube (practicing loop knot tying), blood vessel model (selective placement of hemostatic suture and tying of knots), and sponge cloth model (placing of various stitches and practicing different knots).

The task objectives for procedure-specific skills are:

1. Application of single staples and clips.
2. Practice with a mechanical linear stapler.
3. Performing sharp and blunt dissection.
4. Practice fine dissection.
5. Practice tissue shaping and morcellation.
6. Practice placement of a cyst into a bag for extraction.

An objective scoring system was implemented to assess the skill level of individual trainees before and after training. Eleven exercises were selected and each was assigned an equal point value of 100. Six were scored in number of tasks in 1 minute, and 5 in number of minutes per 1 task. A score of 100 was given for completing a target number of tasks in 1 minute or the assigned task in a target amount of time. A score of 0 was given for not completing a single task in 1 minute of for completing the assigned task in 3 times the target time. Scores between 100 and 0 were set linearly as a function of those values. This system allows for the scoring of results for each trainee in each exercise as well as providing an overall score. Regression analysis is used to estimate the impact (pre-test versus post-test) of each hour of training with the LTS2000, controlling for the years of experience of the trainees.

Two studies have been conducted to measure degree of improvement of laparoscopic skills after training with the LTS2000 using objective pre- and post-training assessments. The studies involved 39 physician users of the training system; 23 at a University Hospital I Kiel and 16 with a University affiliated community hospital in Chicago (figure 73). The physicians had various degrees of experience. Fifteen were attending surgeons and 24 were residents in training. Prior to training, 34 of the 39 physicians scored below the 75th percentile of the maximum achievable score. After training, only 5 scored below that level, which may be considered a benchmark.

	Average	Range
Pre-Test Point Score	534.5 (SD 216.7)	45.0 – 920.8
Post-Test Point Score	957.1 (SD 126.6)	549 – 1100
Hours of Practice	8.7	2 – 30

Figure 73. Results of the training session with LTS 2000

It can be concluded that the scoring system used with the LTS2000 is objective and allows unbiased impact analysis. Preliminary results suggest that skill components associated with advanced laparoscopic surgery may be significantly improved through instructions and sustained practice on an accentuated physical simulator such as the LTS2000. The system is being extended to include a mechatronic component that allows data reflecting selected skills to be displayed for immediate feedback to the users, and collected for comparison and analysis.

What Makes a Skilled Practioner: Learning to be a Doctor (Krummel)

The American Board of Medical Specialties (ABMS) along with the Accreditation Council on Graduate Medical Education (ACGME) have come to a consensus on the 6 components of surgical competence (figure 74). Note that technical skills are within Patient care and Practice-based learning. They are:

- Medical Knowledge
- Patient Care
- Interpersonal & Communication Skills
- Professionalism
- Practice-based Learning/Improvement
- System-based Practice

Figure 74. Components of surgical competence

At the Center for Advanced Technology in Surgery at Stanford (CATSS) there are 4 different simulators: Human Patient Simulator™ , bronchoscopy trainer, anastomosis trainer and CathSim™. The simulators have been evaluated using a standard assessment protocol for usability, validity (content, construct and criterion), transferability, comparison to existing modalities and cost-benefit analysis.

The anasotomosis simulator (figure 75) is a virtual reality (VR) simulator which has a high fidelity 3-D graphic computer generated representation of a hollow structure (intestine, blood vessel, ureter, etc) and surgical instruments, and a haptic interface using two Phantom haptic device (figure 76). The simulation has physics-based tissue interactions, and analysis software to measure and evaluate performance of an open surgery anastomosis. In order to determine if such a simulator can teach and/or measure surgical skills, a study with 8 experienced surgeons and 12 medical students was conducted. The 8 parameters measured were: Tissue damage, accuracy, peak tearing force, time to completion, surface damage, angular error, tool tip travel distance and overall error. The study also accounted for dominant versus non-dominant hand, 3-D needle guidance and control of needle holder. The performance analysis software automatically tabulated the participant's score and printed out a report at the completion of the procedure (figure 77). There is also an option to have a real-time graphic analysis of the amount of pressure which is being used in order to provide instant feedback ("proximate learning").

Figure 75   Anastomosis Simulator
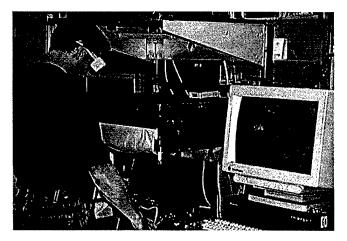
Figure 76 Phantom haptic interface

The results of the study demonstrated construct validity since the experienced surgeons performed better than students, and training transfer in that 6 of 7 students demonstrated improvement with repeated trials. Some limitations of the study are small sample size which did not completely validate the proposed metrics as measures of surgical skills, whether there is transfer of skills to the OR, and the device was a prototype. There is also the question of the part-task trainer. "It is not true that a complex reaction consists of a chain of separate processes which may be arbitrarily added and subtracted." L.S. Vygotsky, "Mind in Society").
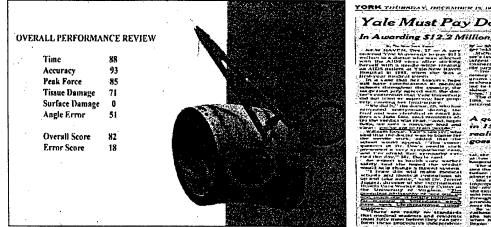
Figure 77 Automatic report generated at end of trial.

Figure 78 Consequence of poor training

Even seemingly simple tasks like starting an intravenous (IV) catheter can have serious errors and consequences. In December, 1997 a physician at a prominent medical training institution lost litigation for infecting a patient with AIDS after a needle stick . The "… jury cites faulty medical training…" as the cause. A commercially available simulator from Immersion Medical Corporation to train the starting of an intravenous (IV) – CathSim™ has been studied by the SurgSim group at Stanford University Medical Center. A total of 114 students (novice =28, medical student = 42, and registered nurses (RN) = 44) participated in the evaluation of CathSim™ In the novice study (n=28), the group all had a didactic session, then divided into two groups – CathSim™ and mannequin simulator – then started an IV catheter on a real a person.. The CathSim™ trained students were better at advancing the catheter on real patients. The mannequin group reduced subjective rating from pre to post real procedure for feeling of preparedness to do a real procedure (p=.043) and usefulness of mannequin for training (p=.002). The conclusions were that skill transfers from CathSim to real procedure were better than from the mannequin arm to real procedure in at least one skill and the CathSim™ promotes a more realistic understanding of the procedure and the student's ability level. This study also established usability and transferability.

In the medical student group (beginner = 14, intermediate = 10 and expert =17), the experts performed better than intermediates, who performed better than beginners (construct validity). The test results were: Same needle re-stick (p=.019), extra needle-catheter units used (p=.002), tourniquet time (p=.000), pain factor (p=.022) and misuse of tools (p=.002). In addition content validity was established – expert physicians felt simulator experience resembled the way an IV should be performed and was realistic and useful (graphic images, mock catheter, haptic feedback of skin traction and needle insertion).

In the nurse study (beginners =16, intermediates =9 and experts = 19), the experts performed better than intermediates, who performed better than beginners (construct validity). In addition, needle recannulations (p=0.036) and misuse of tools (p= .003) were in the same trend from expert to beginner.

It must be emphasized that the technical skills are but one component which complements the entire spectrum that comprises surgical competence. Not only are there psychomotor, visio-spatial and perceptual skills, but also knowledge, judgment, analysis, thought about action and translation of thought into action. It is critical to build on what medical education does right and use the power of simulation to make it better.

Fundamentals of Laparoscopic Surgery (SAGES). A New Standard in Education for Laparoscopic Surgery (Fried)

In reviewing the rationale for training in laparoscopic surgery, it is found that beyond laparoscopic cholecystectomy, residents' experience in laparoscopy is extremely variable with a few programs providing an excellent experience in advanced procedures, but the majority having no advanced experience or unequal exposure on one or two services. Approximately 10% of the graduating resident's case experience is laparoscopic; however, only 1% of their experience is in laparoscopic procedures other than laparoscopic cholecystectomy and individual experiences in advanced procedures vary widely. A survey by the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) reveals that despite the best educational efforts of academic groups like SAGES there are still only a few laparoscopic "champions" as educators, poor patient and referring physician awareness of less invasive surgical options, a paucity of outcomes data documenting effectiveness of laparoscopic surgery and a lack of comfort with laparoscopy as a surgical tool. Surgeons reported that they are uncomfortable in pursuing advanced laparoscopic procedures because they learned laparoscopy by memorizing the techniques for a few procedures and because there may be a low level of understanding and comfort with the basics of laparoscopy.

The rationale behind the SAGES Fundamentals of Laparoscopic Surgery (FLS) course is if residents and their teachers can be taught the underlying fundamentals of laparoscopy, including cognitive and motor skills, they will be more comfortable with the use of these techniques as a general surgical tool. This will lead to wider use and improved patient care. The model is the ATLS course because it has a *basic* instructional course in trauma care that teaches *standardized* basic information with *hands-on* training to develop motor skills and had validated pre- and post-testing to document learning. Therefore the FLS was designed as an integrated study course that includes an instructional (CD ROM based) guide that verbally and visually teaches the fundamental components of laparoscopic surgery. It includes situational interactive case studies to develop judgment skills and has a pre- and post-op testing module to grade cognitive learning. In addition, FLS incorporates a manual skills testing module to allow practice and assessment of basic laparoscopic maneuvers designed to increase the eye-hand skills needed to work in the video endoscopic surgical milieu. These tasks are non-procedure specific.

The Didactic Section contains a CD ROM with study guide, test and reference. There are didactic chapters (well illustrated), pre- and post-tests (via Internet), interactive case scenarios and

manual skills test introduction. The Manual Skill Station is a simple laparoscopy box tied to CD ROM for "watch & do" exercises with measurable exercises to quantify ability and improve skills.
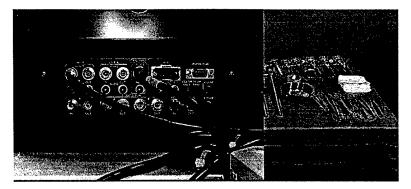
Figure 79 Identification of equipment and laparoscopic instruments.

The components of the Didactic Section are: Identification of instruments/equipment (figure 79), recognition of complications (figure 80), anesthesia position for laparoscopic surgery (figure 81), and recognition of laparoscopic findings. There are case scenarios which are designed to familiarize and test for access methods in laparoscopy, equipment needs, interpretation of findings, management of complications, trouble shooting, physiology and pre- and post- operative care.
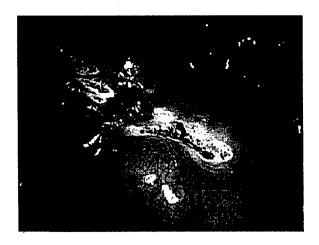
Figure 80 Complications   Figure 81 Anesthesia positioning

In testing and validation of the didactic session there is a stringent process which resulted in the creation of questions which were analyzed for content validity (determined by review by panel of experts) and construct validity (Does test measure competence by showing differences in test scores between competent and non-competent surgeons?). The content was created by a comprehensive review

in defined subject areas. Each question is tested for relevance and is agreed upon by consensus defined by reference group of experts.

Validation is currently being conducted in a multi-institutional study of beta sites with a reference group of experts. The purpose is to compare scores between competent and non-competent laparoscopic surgeons, however it may be necessary first to define competent and non-competent groups by some other criteria and attempt to relate score on individual questions to total score.

The goals for the FLS are to provide a uniform curriculum for the acquisition of basic knowledge and technical skills in laparoscopy. The FLS course will be a reliable and valid process for certification of competence in basic laparoscopy which may become a new model for training as more technology-dependent surgical advances are introduced.

Surgical Competence: A Perspective of American Board of Medical Specialties (Narhwold)

There is a growing public dissatisfaction with the medical profession subsequent to publicizing of medical errors as well as the variations in care and perception of poor service. The public is demanding "I want a competent doctor". In response to the need for accountability, the American Board of Medical Specialties (ABMS) investigated what constitutes medical competency.

In order to accurately identify the requirements of competency, it is necessary to look at the four segments of a physician's life. Initially knowledge and degree/certification begins with premedical school resulting in an undergraduate baccalaureate degree. Medical school leads to a medical doctor (MD) degree. Residency training results in state licensure. Once in practice, certification is required. The responsibility of degree granting, accreditation and certification is conducted by different bodies during the 4 stages of development. In premedical school, the university grants the degree, whereas after medical school there is the Liaisons Committee on Medical Education (LCME). During residency, the Accreditation Council on Graduate Medical Education (ACGME) and Residency Review Committee (RRC) are the responsible authorities. During practice, the individual professional societies of the ABMS are the responsible authorities.

To date, certification comes with an examination which is independent of the physician's practice. There must be an overhaul of the system with a linkage between education and accreditation and certification. There must be a connection between the process of evaluation of competency and outcomes

The ABMS and ACGME have agreed upon a description of general competency (figure 82). The critical features are: 1. Knowledge, 2. Patient care, 3. Interpersonal and communication skill, 4. Professionalism, 5. Practice-based learning & improvement, 6. System-based practice.

General Competencies	Maintenance of Certification
1. Knowledge 2. Patient care 3. Interpersonal and communication skills 4. Professionalism 5. Practice-based learning & improvement 6. System-based practice	1. Evidence of professional standing. 2. Evidence of lifelong learning and quality improvement. 3. Evidence of cognitive expertise. 4. Evidence of practice performance.

Figure 82 General Competencies   Figure 83. Maintenance of certification

The American Board of Medical Specialties is an umbrella organization representing 24 member boards which issue 112 certificates. A consensus report included a description of the competent physician as follows:

> *"The competent physician possesses the medical knowledge, judgment, professionalism, and clinical and communication skills to provide high quality patient care."*

Patient care encompasses the promotion of health, prevention of disease, and diagnosis, treatment and management of medical conditions with compassion and respect for patient and their families. Certification of patient care skills should include periodic oral examination, record review, morbidity and mortality conference, direct observation, case/procedure log, hospital credentialing and SIMULATION. Simulation provides a method by which measurements can quantify performance. A point to remember is that "What we measure we tend to improve." (David Leach, MD – Director, ACGME). In addition, the maintenance of competence should be demonstrated throughout the physician's career by evidence of lifelong learning and ongoing improvement of practice (figure 83).

Surgical Competence: The Medium is the Message. A Perspective of the Accreditation Council of Graduate Medical Education (Dunn)

As a background on the Accreditation Council of Graduate Medical Education (ACGME), the responsibility and mission is to improve the quality of health care in the United States by ensuring and

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improving the quality of graduate medical educational experiences for physicians in training. The ACGME accredits 7,800 residency programs in 26 core specialties and 77 subspecialties, utilizing peer review process by 26 Residency Review Committees (RRC), including General Surgery as one of the core specialties.

Until recently, the process (or "old system") was basically an audit methodology, evaluating comprised such aspects as "Does the program comply with the Requirements?", "Does the program have established goals and objectives and an organized curriculum?", and "Does the program evaluate its residents and itself?" So even though a program met the above criteria, modern educational processes have recognized the importance of objective measurements and outcomes analysis. To that end, the ACGME has instituted a new Outcomes Project. This is a long-term initiative to enhance residency education through educational outcome assessment. Instead of the audit approach above, the project addresses issues such as "Do the residents achieve the learning objectives set by the program?, "What evidence can the program provide that they do so?", and "How does the program demonstrate continuous improvement in its educational processes?" This requires a new strategy to identify and quantify what to measure, to develop measurement tools and to collaborate to find the answers.

In order to identify what to measure, an extensive review of literature (2500 articles) with an initial list of 84 competencies was conducted. An Advisory Committee gave counsel, and there was extensive vetting (RRC members, program directors, residents, corporate leaders, university presidents, public). Support was acquired through the Robert Wood Johnson Foundation. The areas to be measured include: Patient Care, medical knowledge, practice-based learning and improvement, interpersonal and communication skills, professionalism and systems-based practice. Each assessment method included the measures of description, use, psychometric qualities, feasibility/practicality and references. This review resulted in a report and web-based educational instrument entitled "Toolbox of Assessment Methods" which was issued jointly by the ACGME and the American Board of Medical Specialties (ABMS). For example, the toolkit on the use of simulators indicates (figure 84):

In order to measure technical competency, there must be a model of mental activities in directed skill acquisition at specific levels: Novice, competence, proficiency, expertise and mastery (Stuart and Herbert Dreyfus). At the novice level, the beginner is given "rules" for basis of action in a context-free experience and progresses by bringing behavior into conformity with the "rules". At the competence level and with experience over time, the student observes patterns and learns "guidelines" instead of discrete rules. Simulation is especially useful at these two beginning levels. By the proficiency level, the surgeon should be prepared to deal with a wide variety of situations and understand the

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SIMULATIONS AND MODELS Page 13

DESCRIPTION

Simulations used for assessment of clinical performance closely resemble reality and attempt to imitate but not duplicate real clinical problems. Key attributes of simulations are that: they incorporate a wide array of options resembling reality, allow examinees to reason through a clinical problem with little or no cueing, permit examinees to make life-threatening errors without hurting a real patient, provide instant feedback so examinees can correct a mistaken action, and rate examinees' performance on clinical problems that are difficult or impossible to evaluate effectively in other circumstances. Simulation formats have been developed as paper-and-pencil branching problems (patient management problems or PMPs), computerized versions of PMPs called clinical case simulations (CCX®), role-playing situations (e.g., standardized patients (SPs), clinical team simulations),...

Figure 84 Example of simulation webpage of ACGME from Toolkit of Assessment Methods

procedure in terms of relevance for long-term goal. At this time "Principles and Maxims" are used. Expertise implies a repertoire of experience so vast that situations dictate an intuitively appropriate action. Ultimately there is the achievement of mastery to a point that learned skills can cope with novel and unpredictable responses from complex adaptive systems. In a complex adaptive systems the parts have the freedom and ability to respond to stimuli in many different and fundamentally unpredictable ways. A distinction must be made between systems that are largely mechanical and those that are naturally adaptive; the simulated surgical patient is an example of the former; the living patient an example of the latter.

What is left out of our assessments may be as important as what is included. Each technology, in itself valuable for teaching and assessment, should be kept in proper perspective and the relationship to the larger integrated whole — the result is the competent physician.

In attempting to define the competent physician, the ACGME and ABMS joint outcomes project decided that it is nearly impossible to establish a concrete definition; therefore a *description* is that the competent physician should possess the medical knowledge, judgment, professionalism, and clinical and communication skills to provide high-quality patient care. Patient care encompasses the promotion of health, prevention of disease, and diagnosis, treatment, and management of medical conditions with compassion and respect for patients and their families. Maintenance of competence should be

demonstrated throughout the physician's career of lifelong learning and on-going improvement of practice.

Goal II: DEFINITIONS

The definitions of what are the specific meaning and connotations within the context of objective measurements is best derived from the science of behavioral psychology, which has had decades of research in this area. Many subtopics have been spawned, such as psychometrics, ergonomics, man-machine interface, human interface technologies, etc, and each has slightly differing nuances. Thus, the definitions for basic words such as ability, etc were taken from the New Webster's Dictionary of the English Language (Deluxe Encyclopedic Edition) Delaire Publishing, Inc NYC;1981 (Appendix 2), while those definitions for validity and reliability were taken from : Reber, AS: Dictionary of Psychology. (Appendix 3).

There was much debate about the definition of "ability", which in the behavioral psychology and objective assessment literature specifically refers to those characteristics with which a person is born or develops in childhood and which, in general, are not subject to improvement by training exercises. Unfortunately there are numerous other connotations for abilities, specifically implying the converse of "disability", with the many legal ramifications of excluding a person because they do not possess a high enough quality of fundamental abilities and therefore could seek refuge and compensation under the Americans With Disabilities Act, to mention just a few potential conflicts. Nevertheless, it was emphasized that everyone has abilities, it is just that some people have more than others. The term abilities is so entrenched in the scientific literature that, though being mindful of the potential non-scientific implications of the term, it was a non-consensus (though majority) opinion that the term abilities most appropriately defines what was scientifically intended (aptitude was suggested as an alternative, though the connotation here was more of a potential than a measurable level of physical capabilities).

"Skills" are the fundamental abilities which are brought together through training to create the basic psychomotor actions which a person possesses and which are improved with training. "Tasks" are a set of skills which are used to perform a specific action (such as an anastomosis), whereas a "procedure" is all the tasks choreographed together to create a surgical operation.

A common method of scientifically analyzing specific (surgical) procedures is called "task deconstruction". The presumption is that complete procedures (like cholecystectomy) are comprised

of a number of "tasks" (like isolating the cystic duct) which in turn is composed of a series of "skills" (like bimanual dexterity, transfer, traversal, blunt dissection, clamping) and these are based upon fundamental psychomotor, visio-spatial and perceptual abilities (such as precision aiming, tracking, hand-arm steadiness, eye-hand coordination speed, etc). Thus the overall structure of increasing complexity mentioned above is abilities, to skills, to tasks, to procedures. This progression will provide a set of definitions which can be applied the various simulators to determine the specific exercise (training or testing) level of complexity and provide insight as to where in the training of technical skills that the exercise can be applied.

In recognizing that technical skills are just a portion of the overall composition of "technical competency" and that technical competency was just a portion of a surgical competency. A number of definitions related to competency that were referred to during the presentation of the simulation systems were also defined, in accordance with the same dictionary terminology as above. These terms included competent/competence, proficient/proficiency, exercise and system (Appendix 2). The workshop therefore has specific definitions which were used in the context of technical skills but based upon a broader definition to real world usage.

Goal III: TAXONOMY

A taxonomy (Greek *taxis* = arrangement and *nomie* = method) is a method of arranging or classifying larger entities, groups or systems into an ordered system, usually in a hierarchical fashion that indicates natural relationships. Once the definitions of the individual words to be used were agreed upon, other components of simulation were brought into the overall classification. Although recognizing the importance of overall competence, the workshop focused only upon developing a taxonomy for technical skill, and specifically the manual (but not the cognitive nor behavioral/social skills). Thus the derived taxonomy (Appendix 4) includes abilities, skills, tasks and procedures as applied to their use by educational systems for training and objective assessment of surgical skills. More specifically, the derived taxonomy only contains those exercises which currently are employed by simulators available today. It is acknowledged that this list is not comprehensive, and that some future simulators will add new abilities, skills, tasks or procedures. It is envisioned that, with this baseline taxonomy, future researchers will refer to the categories and designate where the components of their simulators fit. The ultimate goal (development of the core curriculum) is that the exercises from the

simulators will fit into a "toolbox" which educators and surgical program directors can use in establishing a training and evaluation curriculum.

Goal IV: MATCHING METRICS TO CURRENT SYSTEMS

A total of 13 different simulation systems (from synthetic materials in open surgery drills, to animal parts in open and laparoscopic systems, to full virtual reality in both open and laparoscopic skills) that were reviewed in the first session were matched against the measurements (metrics) that were identified in the taxonomy (Appendix 5). This synthesis provides a "look-up table" for program directors and other educators in helping create a training curriculum that is comprehensive (i.e. which covers the basic abilities, skills, tasks and procedures) within the context of what is available today. Since no single system covers all the components of surgical technical skills, a number of different methods and simulators will need to be combined to provide the learning experience for the resident/registrar. In reviewing what is available, it is apparent that only a few exercises are available for fundamental abilities (though they are very well validated) while there is a plethora of simulations for skills and tasks. Full procedures are too complex to simulate, other than in performing them in an animal model. Simple, low fidelity systems (from box trainers to virtual reality) can cover a significant part of the early learning for a full procedure (egg, cholecystectomy), however it will be a significant time frame before that level of sophistication can be brought to the personal computer level.

Goal V: DEVELOPMENT OF A CORE CURRICULUM

There was lively debate about deciding upon a core curriculum. One of the major difficulties is that different training programs (especially on an international basis) have different rates at which students are introduced to technical skills. There are important differences which make the creation of a "standard" core curriculum very difficult at this time in the developing science of simulation. Therefore, it was agreed that classification of training/evaluation should be according to three levels of difficulty – basic, intermediate and advanced (Appendix 6). Abilities, skills, tasks and procedures were therefore categorized as to whether they were basic, intermediate or advanced level of difficulty and clinical applicability. By this approach offers a toolbox of exercises (similar to the ACGME toolkit) with which training program directors can customize their training/evaluation program according to their educational needs and even (perhaps) to the skill (and learning curve) of the individual student or group of students (egg PGY 2, 3). Over time, as more simulators become available and validated, it may be

possible to create a standard core curriculum for an (inter)national training program. However the nascent field of objective assessment has not progressed far enough at this time to have the outcomes that would scientifically support one specific curriculum. It may also be possible that this toolbox can be incorporated into larger efforts, such as the ACGME, ABMS or NBME in the United States to provide the technical component to compliment the overall assessment of competence.

CONCLUSION

The essential goals of the workshop to establish a consensus on definitions and taxonomy (classification) of specific educational, training and evaluation exercises that are available in today's simulators were met. The goal of establishing a curriculum was not met; instead, levels of training (basic, intermediate and advanced) with simulation exercises available at each level, were provided in order that individual training program directors could construct and customize a training program dependant upon local needs.

There are a few identified areas for future research. While realizing this is not a comprehensive list, it represents a few glaring absences in the current arena that should have near-term research for resolution. While definitions for many aspects were proposed and agreed upon, there was only a speculation and listing (from "brainstorming") on what constitutes an error (Appendix 8), what is a taxonomy for errors, and how errors should be measured. In addition, there were three distinct areas for research that were identified during the workshop. 1). A number of surgeons identified a need for a skill called "tissue handling". None of the systems measure such a skill. 2). There are only a few exercises which evaluate fundamental abilities; it is known that there are many such tests available in the non-medical arena and therefore these should be identified and validated. 3). Comparison and integration of the various available exercises of the different systems into a single coherent "core curriculum".

It is anticipated that, as the field of objective assessment using simulators matures with validation by outcomes analysis at the end of the training programs, there will be a convergence toward a core curriculum that can provide a standardization for surgical resident training and evaluation as well as certification – all directed at reducing errors to improve the quality of patient safety.

ADMINISTRATIVE ACTIONS

The After-Action for this workshop is illustrated in the timelines and deliverables (Appendix 9), which includes providing a final report by 1 September, 2001. Circulation to numerous relevant societies and agencies for vetting (Appendix 10) will occur prior to setting an Open Forum of the general surgical education community. A Board of Advisors was elected. (Appendix 11) and an Agenda of the workshop is included for archival purposes.

Abbreviations

ABMS	American Board of Medical Specialties
ABS	American Board of Surgery
ABSITE	American Board of Surgery In-training Exam
ACGME	Accreditation Council of Graduate Medical Education
ACS	American College of Surgeons
ADEPT	Advanced Dundee Endoscopic Psychomotor Tester
AIDS	Acquired Immune Deficiency Syndrome
ALARP	As low as reasonably possible
AMC	Acquired Master Surgeon
AST	Advanced Surgical Training
ATLS	Advanced Trauma and Life Support
BSS	Basic Surgical Skills
BST	Basic Surgical Trainer
CATSS	Center for Advanced Technology in Surgery at Stanford
CCrISP	Care of the Critically Ill Surgical Patient
CD-ROM	Compact disc- Read only memory
CTPS	Combat Trauma Patient Simulator
DoD	Department of Defense
DPL	Diagnostic Peritoneal Lavage
EAES	European Association of Endoscopic Surgeons
EGD	Esophago-gastro-duodenoscopy
EMST	Early Management of Severe Trauma (the RACS implementation of ATLS)
ENT	Ear-nose-throat (Otolaryngology)
ES3	Endoscopic Sinus Surgery Simulator
GAO	Government Accounting Office (United States)
GRIP	Gabriel-Rosser Inanimate Proctor
ICC	Inter-Class Coefficient
ICSAD	Imperial College Surgical Assessment Device
IPT	Integrated Product Team

IRT	Integrated Research Team
ITER	In-training Evaluation Report
IUO	Innately Unbelievable Operators
IV	Intra-venous
LTS 2000	Laparoscopy Training Simulator 2000
MAS	Minimally Access Surgery
MISSIMU	Minimally Invasive Simulator
MIST-VR	Minimally Invasive Surgery Trainer – Virtual Reality
MISTELS	McGill Inanimate System for Training and Evaluation of Laparoscopic Skills
MM&S	Medical Modeling and Simulation
MSTI	Medical Simulation Training Initiative
NCAMSC	National Capital Area Medical Simulation Center
NCSSC	National Consortium of Surgical Simulation Centers
OSATS	Objective Structured Assessment of Technical Skills
OSCE	Objective Structured Clinical Exam
PC	Personal computer
PGY	Post Graduate Year
PicSOr	Pictorial Surface Orientation
PMP	Patient management problem
RACS	Royal Australasian College of Surgeons
RCS	Royal Colleges of Surgeons (England, Ireland, Scotland)
RRC	Residency Review Committee
SAGES	Society of American Gastrointestinal Endoscopic Surgeons VAS
SD	Standard Deviation
SP	Standardized patients
TATRC	Telemedicine and Advanced Technology Research Center
TEMS	Trans-anal Endoscopic Micro-surgery
VR	Virtual Reality

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University of Helsinki, Gold Medal - 1989
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Surgical Education Audio-visual Prize, Association of Surgeons of Great Britain & Ireland: 1984, 1986, 1990, 1992.
Honorary member SAGES, 1991
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Honoray member SSAT, 1994
Honorary Fellow, Italian Surgical Society, 1994
Scott-Heron Medal, Royal Victoria Hospital, Queen's University of Belfast, 1995
Ernest Miles medal, 1996
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Royal College of Surgeons of Edinburgh, Gold Medal, 1997
Knight Bachelor - Her Majesty Queen Elizabeth II, 1998
Fellow of the Royal Society of Edinburgh – 1998
Queen's award for higher and continued education, 1999
Excel Award of the Society of Laparoendoscopic Surgeons 'for outstanding contributions to laparoscopy, endoscopy and minimally invasive surgery – 2000
George Berci Lifetime Acchievement Award Society of American Gastrointestinal Endoscopic Surgeons for 'outstanding contributions , innovative developments, research and training in endoscopic surgery' : April 2001
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Books – 27

DARZI, Professor Ara, MD, FRCS, FRCSI, FACS

Professor Darzi studied medicine in Ireland and qualified from the Royal College of Surgeons. He obtained his fellowship in Surgery from the Royal College of Surgeons in Ireland and a M.D. degree from Trinity College, Dublin. He was subsequently granted the fellowships of the Royal College of Surgeons of England and The American College of Surgeons

Currently Professor Darzi holds the Chair of Surgery Imperial College, Science, Technology and Medicine and is an Honorary Consultant Surgeon at St. Mary's Hospital NHS Trust. Professor Darzi is also the Tutor in Minimal Access Surgery at the Royal College of Surgeons in England.

In the past he has been a Hunterian Professor of the Royal College of Surgeons of England and the James The IV travelling fellow for 1999/2000. He was also a Council member of the Association of Coloproctologist of Great Britain and Ireland, The Association of Endoscopic Surgeons of Great Britain and Ireland, and the Society of Minimal Invasive Therapy.

He has also delivered many prestigious named lectures in the past, the most notable of which include the Robert Smith Lecture, The Zachary-Cope Lecture and The Sylvester O'Halron lecture.

Professor Darzi's main clinical and academic interest is Minimal Invasive Therapy, including Imaging and Biological research and he has published widely in the field of minimally invasive therapy. He has co-authored over 100 peer review publications and five books in surgery.

Recently Professor Darzi was elected to the National Modernisation Board by the Secretary of State for Health and currently advises the government on modernising the NHS. He also chairs the London Modernisation Board.

The Queen honoured the department with the Queens Anniversary Award for higher education in November this year

DEANE, Professor Stephen A, MBBS, FRACS, FRCS(C), FACS

Professor Deane is a Fellow of the Surgical Colleges of Australasia, Canada and America. He occupies (1992) the foundation Chair of Surgery (UNSW) at Liverpool Hospital, Sydney, where he maintains a strong interest and involvement in UGI and HPB surgery. He has been prominent in promoting and achieving new standards of trauma care at State and National levels in Australia for more than 15 years and has lectured extensively on trauma subjects in Australia and internationally. He led the EMST (ATLS®) programme in ANZ from 1987 to 1996. He is an active member of the American and International Trauma Surgery Associations. Responsibilities and recognition within the Royal Australasian College of Surgeons (RACS) have included membership of Trauma Committee, RACS Foundation Lecturer for Trauma Section of Annual Scientific Congress 1996, recipient of RACS Medal in 1997 and election to Council of the RACS in 1998. He took up Chairmanship of the RACS Board of Basic Surgical Training in May 2001. He is the Australian and New Zealand representative on the Board of Governors of the American College of Surgeons. He is President Elect of IATSIC (International Association for the Surgery of Trauma and Surgical Intensive Care). Professor Deane has chaired two RACS Committees which are involved in new initiatives in surgical skills training and surgical skills laboratory development. He has had a key role in the early development of the Definitive Surgical Trauma Care (DSTC) Course within IATSIC and the Australian surgical community.

DUNN, Marvin R., M.D

Dr. Dunn is a board certified pathologist and currently the Director of RRC Activities for the ACGME. Dr. Dunn has previously served as the Director of the Division of Graduate Medical Education and Secretary to the Council on Medical Education of the American Medical Association, and as Dean at both the University of South Florida College of Medicine and the University of Texas Medical School at San Antonio.

FRIED, Gerald M., M.D. FACS

Dr. Fried graduated from McGill University Faculty of Medicine in 1975. He then completed his residency in general surgery at McGill University in 1980, which included one year of training in gastrointestinal surgery at Ohio State University under the supervision of Dr. Larry Carey and Dr. Robert Zollinger. He then completed a research fellowship in gastrointestinal endocrinology at The University of Texas Medical Branch, Galveston, under the direction of Dr. James C. Thompson. This involved the study of cholecystokinin and its the physiologic effects on the biliary tract and pancreas.

Dr. Fried returned to McGill University and The Montreal General Hospital in July 1982, and has remained there since. He has maintained research funding for most of that time for basic or clinical research, and has been involved actively in surgical education. He was Program Director for General Surgery from January 1991-December 1996, and Fellowship Director in Endoscopic Surgery since 1996. He is currently Professor of Surgery, Associate Head of Surgery (Clinical) for the Montreal General Hospital site of the McGill University Health Centre, Director of the Section of Minimally Invasive Surgery at McGill University, and Director of Gastrointestinal Surgery and Minimally Invasive Surgery at The Montreal General Hospital. He is also Director of The Florenz-Steinberg Bernstein and David Bernstein Centre for Research and Education in Minimally Invasive Surgery, and Director of Tyco Healthcare/United States Surgical Corporation Centre of Excellence Program at McGill University.

He has been Chairman of the Committee on Endoscopic and Laparoscopic Surgery of the Canadian Association of General Surgeons, is currently Chair of the Patient Care Committee of The Society for Surgery of The Alimentary Tract, and co-chair of SAGES committee on The Fundamentals of Laparoscopic Surgery Program. His current academic interests are in training and evaluation of laparoscopic skills, and measurement of patient-based outcomes after minimally invasive surgery. His clinical interest is in gastrointestinal surgery, and the multidisciplinary application of endoscopic, imaging, and minimally invasive technologies in the care of patients with digestive diseases.

GALLAGHER, Anthony, PhD

Dr. Gallagher completed his BSc at the University of Ulster in 1988 and then his PhD in Psychology at Trinity College Dublin in 1992. He is a Consultant at the Royal Victoria Hospital in Belfast, Director of Research at the Northern Ireland Center for Endoscopic Training and Research (Royal Group Hospitals Trust & Queen's University Belfast), founding member and one of the Directors of the Queen's University Advanced Informatics in Medicine (AIM) Research Institute.

He is currently Fulbright Distinguished Scholar at the Department of Surgery at Yale. In minimal access surgery (MAS) he has three research areas, optimal skill acquisition strategies in MAS, human factors in MAS and objective assessment. For the last six years he and his colleagues have been investigating different training strategies which will allow surgical residents to automate quickly to the counterintuitive eye-hand co-ordination required for MAS. In particular they have been investigating the use of virtual reality (VR) trainers. Their published research evidence shows that VR trainers are at least as good, if not better, in achieving basic psychomotor performance levels which are currently established on traditional box trainers. He and his group have also been quietly working on the development of an objective assessment protocol of fundamental abilities (i.e., visio-spatial, perceptual & psychomotor) for MAS. This protocol and a number of empirical replications were reported for the first time at the EAES in Maastricht 2001.

At the Dept. of Surgery at Yale University along with Faculty members (Richard Satava MD, Dana Anderson MD, Neal Seymour MD and Sanziana Roman MD) they have been investigating whether training on VR transfers to performance in the operating room. They have also been investigating how strongly objectively assessed fundamental abilities predict performance in the operating room. This study will conclude in August 2001.

HAMDORF, Jeffrey M, MBBS, Ph D, FRACS

Dr. Hamdorf is a Senior Lecturer in the University Department of Surgery at the Queen Elizabeth II Medical Centre. His interests include Gastrointestinal Surgery, Upper Gastrointestinal Malignancy and Neoadjuvant chemoradiotherapy as well as Surgical Education, Curriculum Development and Surgical Skills Development

His Career Progression began with Surgical Research Scholar, University Department of Surgery, UWA (1987), followed by Surgical Registrar, Interhospital Rotation, Western Australia (1989). In 1993 he became a Visiting Academic at the University of New South Wales, then aSurgical Fellow, The Prince of Wales Hospital, Randwick, NSW(1994). Since 1995 he has been Consultant Surgeon, Sir Charles Gairdner Hospital and Senior Lecturer in Surgery, The University of Western Australia. His teaching experience and appointments include University Department of Surgery Teaching Group (Chair 2000, Deputy 1998), Member, Association of Surgical Educators (1999), Basic Surgical Skills Committee, Basic Surgical Training, RACS (Chair 2000, Deputy 1998), State Supervisor (Western Australia), Basic Surgical Training, RACS (2000), Surgical Director, CTEC, The Centre for Medical and Surgical Skills, UWA and the Assessment Committee, The University of Western Australia

HASSON, Harrith M., MD FACOG

Dr. Hasson graduated from Ein Shams University, Cairo, Egypt, 1955 and served internship at Ein Shams University, Cairo, Egypt- 1955-1956, and St. John's Episcopal Hospital, Brooklyn, N.Y. - 1958-1959. His residency in Pathology at St. John's Episcopal Hospital, Brooklyn, N.Y. 1959-1960, and a second residency in OB/Gyn, Presbyterian St. Luke's Hospital, Chicago, IL 1960-1961, and West Suburban Hospital Oak Park, IL, 1961-1963 and 1965-1966. He is certified by the American Board of Obstetrics and Gynecology, 1969, and licensed to practice medicine in the State of Illinois. His hospital Appointments are Grant Hospital of Chicago, Chairman, Department of Obstetrics/Gynecology, (1981-1995); Weiss Memorial Hospital, Director, Gynecologic Endoscopy Center, (1995-)Chairman, Division of Obstetrics/Gynecology, (1996-) Co-Director,

Minimally Invasive Surgery Center, (1998-). His university affiliations are Northwestern University, Assistant Professor, Obstetrics and Gynecology, (1976-1981), Rush Medical College, Associate Professor, Obstetrics and Gynecology, (1981-1995) and University of Chicago, Clinical Professor Obstetrics and Gynecology, (1996-)

Dr. Hassan has been director and officer of several organizations including the American Association of Gynecologic Laparoscopists (AAGL), Society for the Advancement of Contraception (SAC),-The Accreditation Council of Gynecologic Endoscopy (ACGE) and the Chicago Gynecological Society. In addition he has been Program Director for more than 20 continuing medical education programs related to endoscopy and gynecology held in the USA and abroad., a consultant to several organizations including International Fertility Research Program, Planned Parenthood Federation, Program for Applied Research on Fertility Regulation and the RAND Corporation. He is the current Editor of The Journal of the American Association of Gynecologic Laparoscopists and AdHoc reviewer for numerous journals.

Dr. Hasson has received numerous professional honors for developing the Hasson Technique of open laparoscopy and he received certificates of Merits and awards from the American Fertility Society, 1977, the AAGL, 1993, the SLS, 2000. He is a Biographee in Who's Who in Technology Today and Who's Who of American Inventors. He has published 53 original articles in peer reviewed journals and edited a book on IUDs and wrote 24 chapters on several subjects including: open laparoscopy, selective fitting of IUDs, laparoscopic ovarian surgery, laparoscopic myomectomy, and laparoscopic hysterectomy. He has also served as a visiting professor to many University Hospitals in North America, South America, Europe, the Middle East and Australia and produced 30 films and video presentations on surgical procedures shown in the USA and abroad. He now holds 13 grants primarily for research in surgical instruments and procedures. And has received 51 patents for surgical instruments with 2 more pending applications.

HEINRICHS, William LeRoy, MD., PhD.

Dr. Heinrichs is a Professor and Chair (Emeritus, Active)of Gynecology & Obstetrics of Stanford University Medical Center. His education and training include Southwestern State University in Oklahomo, University of Oklahoma School of Medicine and MS/PhD at University of Oregon Medical Sciences University

PROFESSIONAL TRAINING:
1958-1959	Rotating Intern, St. Anthony Hospital, Oklahoma City, OK(affiliate U. of Okla.)
1959-1961	Assistant Resident in Obstetrics and Gynecology, Harper Hospital, Detroit, MI
1961-1962	Senior Resident in Obstetrics and Gynecology, Harper Hospital, Detroit, MI (affiliate of Wayne State University School of Medicine)

RESEARCH AND/OR PROFESSIONAL EXPERIENCE:
1965-1967	Clinical Assistant Professor, Department of Obstetrics and Gynecology, Univ. of Oregon School of Medicine, Portland, OR
1967-1969	Assistant Professor of Obstetrics and Gynecology, Univ. of Washington School of Medicine, Seattle, WA
1969-1972	Associate Professor of Obstetrics and Gynecology, Univ. of Wash. Sch. of Med.
1972-1976	Professor of Obstetrics and Gynecology, Univ. of Wash. School of Medicine

1976-1984	Professor and Chairman, Department of Gynecology and Obstetrics, Stanford University School of Medicine, Stanford, CA
1976-1984	Chief of Service, Department of Gynecol & Obstet, Stanford University Hospital
1976-1984	Member, Executive Committee, Stanford University School of Medicine
1976-1984	Member, Clinical Advisory Committee, Stanford University Hospital
1984-1994	Professor of Obstetrics and Gynecology, Stanford University of Medicine
1985-1994	Director of Gynecology, Department of Gynecology and Obstetrics
1994-present	Professor and Chairman (Emeritus, Recalled 1999), Department of Gynecology and Obstetrics, Stanford University School of Medicine

HONORS (Selected):

1958	Medical Degree with Honors: Student Research Achievement Award (Biochemistry)
1966	Appointment as Josiah Macy, Jr. Faculty Fellow
1970	President's Award, Am. College of Obstet. and Gynecol. (Estrogen Receptors in Brain)
1970-1978	Associate, Acting Editor, Gynecologic Investigation, an International Journal of the Science of Reproduction, Karger, Publ., Basel
1974-1978	Member, PHS (NIH); Study Section, Human Embryology and Development (HED)
1979-1981	Chairman, PHS (NIH); Study Section, Human Embryology and Development (HED)
1978	Chairman, Reproductive Dysfunction Study Group, SCOMSEC - Scientific Group on Methodologies for the Safety Evaluation of Chemicals; sponsored by Scientific Committee on Problems of the Environment (SCOPE), and WHO, Lago Majore, ITALY
1980	Invited Presentation, NIH Consensus Development Conference on Magnetic Resonance Imaging: "Reproduction Toxicity Studies of Gamete and Embryotoxicity, and Teratogenesis", Bethesda, MD
1998	Chairman; Women's Healthcare Session, Medicine Meets Virtual RealityVII, San Francisco
1999	Keynote Speaker, IEEE/CBMS, Stamford, CT, June '99, "From Slices to Surgical Simulation: What Do Surgeons Want?"
2000	Keynote Speaker, MMVR, Newport Beach, CA, Jan.'00, "Envisioning Healing" Organizer: Stereoscopic Image Session, at MMVR, Newport Beach, CA, Jan.'00 Invited Speaker: NIH/NICHD Planning Group (Pregnancy Research) on Nausea & Vomiting in Pregnancy, Bethesda, MD, Oct.'00

KAUFMANN, Christoph R., MD, MPH, FACS, COL, MC, USA

COL Kaufmann is a graduate of the Uniformed Services University of the Health Sciences. He completed his general surgery residency at Tripler Army Medical Center in 1987 and a trauma/critical care fellowship at Harborview Medical Center, University of Washington in 1989. He is board certified in both general surgery and surgical critical care. He is an Associate Professor of Surgery and Military & Emergency Medicine at the Uniformed Services University of the Health Sciences.

He was deployed with the 47th Combat Support Hospital to Desert Shield/Desert Storm including Saudi Arabia and Iraq for which he was awarded the Bronze Star. He served as the Director, Division of Trauma and Emergency Medical Systems, Health Resources and Services

Administration, USPHS, a $5 million annual federal grant program. In 1995, he was awarded the Diploma in the Medical Care of Catastrophes (DMCC) by the Society of Apothecaries of London.

He currently serves as Chief, Division of Trauma and Combat Surgery, USUHS and Chair, American College of Surgeons Army Committee on Trauma, with responsibility for all Advanced Trauma Life Support courses taught in the Army and in Triservice institutions. Dr. Kaufmann is the Principle Investigator for the DoD Testbed for Telepresence Surgery at USUHS, with applications of advanced technology to surgical education being a focus of his research over the past two years. He is the Director of the Surgical Simulation Lab of the National Capital Area Medical Simulation Center. Dr. Kaufmann publishes and presents nationally and internationally on trauma and surgical simulation.

KRUMMEL, Thomas M., MD, FACS

Dr. Krummel is currently is the Emile Holman Professor and Chair of the Department of Surgery of theStanford University School of Medicine. He is a native of Wisconsin and completed his undergraduate degree at the University of Wisconsin with a medical degree at the Medical College of Wisconsin. His surgical residency was at the Medical College of Virginia with a Fellowship in Pediatric Surgery at the Children's Hospital of Pittsburgh followed by a Research Fellowship both at MCV and UCSF. Following five years on the faculty at MCV he was named Professor of Surgery and Chief of Pediatric Surgery at the Pennsylvania State University College of Medicine and Surgeon-in-Chief at the Children's Hospital in 1990. In 1994 he was named John A. and Marian T. Waldhausen Professor and Chair of the Department of Surgery and Surgeon-in-Chief at University Hospitals. In 1998 he moved to Stanford to assume the position as Emile Holman Professor of Surgery and Chairman of the Department of Surgery at Stanford University.

Dr. Krummel is a member of a number of professional societies including the American College of Surgeons, the American Pediatric Surgical Association, the Society for Clinical Surgery, and the American Surgical Association. In 1997 he was named a Director of the American Board of Surgery. He has served in leadership positions in many surgical organizations, and has been fortunate to have participated in the training of a number of medical students and residents who have pursued productive careers in Surgery. Over the last five years he has been a pioneer in the application of information technology to enhance the quality and safety of surgical education and reduce its staggering cost. In collaboration with computer scientists, engineers and industry he has participated in the development of several surgical trainers and has begun the systematic study of their use and efficacy in surgical education.

MAGEE, J. Harvey

Mr. Magee has a diverse background of 30 years' successful professional experience, spanning both military service and private sector business experience. A hospital administrator by profession, Mr. Magee retired from the United States Air Force Medical Service Corps in 1996 at the rank of Major. Upon his retirement from the USAF Surgeon General's Office in 1996, Mr. Magee was the Mid Atlantic Regional Manager for PROMODEL, Healthcare Services Division, representing MedModel, and then joined SHERIKON, Inc. in June 2000 and serves as the Project Officer for Surgical Technology and Medical Modeling and Simulation (MM&S), at the US Army's Telemedicine and Advanced Technology Research Center (TATRC), HQ US Army Medical Research and Materiel Command (USAMRMC), Fort Detrick, Maryland. He coordinates a diverse

Research & Development (R&D) portfolio of advanced surgical and MM&S projects. He is assigned as the Project Officer for TATRC Medical Modeling and Simulation initiatives

Mr. Magee graduated from the University of Mississippi ("Ole Miss") in 1970, with a Bachelors of Business Administration (BBA) in General Business and completed Air Command and Staff College in 1988 and Squadron Officer School in 1987. Mr. Magee was certified by the Federal Aviation Administration 1992 as a Total Quality Management (TQM) Facilitator. During his two separate tours of active duty, Maj Magee received the Meritorious Service Medal, First Oak Leaf Cluster; Meritorious Service Medal, Reserve Medal, and Commendation Medal. He was nominated for Alaskan Air Command Officer of the Year in 1992 and nominated for Young Federal Health Care Administrator in 1991.

From 1970 – 1973, Lt Magee was assigned to USAF Hospital Tyndall, Panama City, Florida, serving as Director, Medical Materiel and Director, Resource Management. From 1973-1976, Capt Magee was assigned to USAF Hospital Bitburg, West Germany, serving as Director, Resource Management and Squadron Commander. And from 1976 – 1978, Capt. Magee served at the Command Surgeon's Office, HQ US Air Forces in Europe. He was Chief, Administrative Support Services, monitoring the administrative effectiveness of 24 USAF medical facilities in Europe. From 1978 – 1979, Mr. Magee was the Western Regional Administrator for The Navigators, Inc., Colorado Springs, Colorado. The Navigators is an international, interdenominational Christian service organization with representatives in more than 30 countries and from 1979 – 1986, Mr. Magee developed, and then managed, a private athletic and fitness facility in Rapid City, South Dakota and also served as an Individual Mobilization Augmentee (IMA) in the USAF Reserves at USAF Hospital Ellsworth, Ellsworth AFB, Rapid City, South Dakota. From 1986 – 1989, after eight years off of active duty in private business, Maj Magee accepted a voluntary recall to active duty in 1986. He was assigned to the Air Force's 2nd largest medical center, USAF Medical Center Wright-Patterson, Dayton, Ohio, as Director of Patient Administration. . From 1989 – 1993, Maj. Magee was assigned to Elmendorf AFB, Alaska, serving as Director of Resource Management, Director of Patient Administration, and Associate Administrator. From 1993 – 1996, Mr. Magee was assigned to the United States Air Force Office of the Surgeon General, Washington, DC, to manage the Wartime Medical Planning System (WAR-MED), Fort Detrick, Maryland. WAR-MED is a $15 million Advanced Research and Development program simulating casualty treatment and evacuation worldwide. Mr. Magee spearheaded and coordinated development efforts of the acquisition community, identified financial and manpower resources necessary to operate and sustain WAR-MED's deployment, and prepared the medical community to deploy and implement this simulation technology

NAHRWOLD, David L., MD FACS

Dr. Nahrwold received his undergraduate and medical degrees from Indiana University, where he also completed residency training in surgery. After service on the faculties at Indiana and Penn State, he was the Loyal and Edith Davis Professor and Chairman of the Department of Surgery at Northwestern University for 15 years.

A gastrointestinal surgeon, his clinical and basic research interests are in the gastrointestinal field, about which he has written extensively. His bibliography lists more than 200 publications. He has served on the editorial boards of nine periodicals and is Editor Emeritus of the *Journal of Laparoendoscopic and Advanced Surgical Techniques.*

Dr. Nahrwold has held elected offices in numerous societies and organizations, including the American Board of Surgery, of which he was Chairman. Currently Emeritus Professor of Surgery at Northwestern, he most recently served as Interim Director of the American College of Surgeons. He is a regent of the College and a member of the executive committee of the American Board of Medical Specialties, of which he is also president-elect.

REGHER, Glenn, PhD

Dr. Regher received his PhD in experimental cognitive psychology from McMaster University in Hamilton, Ontario, Canada in 1993 under the supervision of Dr. Lee Brooks. His thesis work focused on the development of expertise in visual classification tasks (such as dermatological diagnosis). He trained for one year as a research associate in medical education with Dr. Geoff Norman at McMaster University Medical Centre, and joined the University of Toronto Faculty of Medicine as an assistant professor and education researcher in August, 1993. In June 1998, he was appointed as the first Associate Director of the newly established University of Toronto Faculty of Medicine Centre for Research in Education at the University Health Network.

Currently, as well as being the Associate Director of the CRE, Dr. Regehr is Associate Professor in the Departments of Psychiatry and Surgery in the University of Toronto Faculty of Medicine, Associate Faculty in the University of Toronto Department of Education and is a Scientist in the Toronto General Research Institute at the University Health Network. He has chaired the Association of Canadian Medical Colleges Committee on Research in Medical Education for the last four years and has chaired the Association for Surgical Education Research Committee for the last 2 years. He sits on the editorial boards of *Advances in Health Sciences Education* and *Medical Education*, and is a member of the Editorial Research Advisory Committee for *Academic Medicine.*

Dr. Regehr has researched and published in a variety of content domains including, the evaluation of selection procedures for undergraduate and post-graduate training programs, the development of new methodologies for studying self-assessment ability in trainees, the refinement of clinical skills assessment tools such as the Objective Structured Clinical Exam, and the teaching and testing of technical skills in surgery. He has extensive theoretical training and practical experience in experimental and evaluation research methodologies and in inferential and psychometric statistical techniques.

ROSSER, James C. MD FACS

Dr. James "Butch" Rosser, Jr. was born in 1954 in Rome, Mississippi, but despite growing up in the segregated south, he refused to be burdened by its racial, financial, and social barriers. He received his undergraduate degree in chemistry and biology from the University of Mississippi. He completed his medical training at the University of Mississippi School of Medicine before completing a five-year surgical residency at Akron General Medical Center, where in 1984-85 he served as Chief Resident. After his residency, Dr. Rosser began a private surgical practice at Akron General Medical Center and accepted a position as Assistant Professor of Surgery at Northeastern Ohio Universities College of Medicine, where he received the 1991 "Golden Apple Professor of the Year" award for his outstanding contributions to medical education. Early in his career, inspired by Dr. Herbert Awender, Dr. Rosser realized the potential of endoscopic and minimally invasive surgery. He has pioneered a number of minimally invasive procedures, most notably his streamlined laparoscopic suturing technique, and now travels the globe teaching his Laparoscopic Suturing

Symposium and other techniques to thousands of surgeons. He has also distinguished himself by performing laparoscopic cholecystectomy procedures on some of the youngest individuals in the world (15, 17, and 19 months), which earned him Kent State University's "Minority Achievement Award."

Currently, Dr. Rosser is Associate Professor and Director of Endo-Laparoscopic Surgery at Yale University. He has been a contributing editor of <u>Surgical Laparoscopy and Endoscopy</u>, a moderator at the Fourth World Endoscopic Congress, and chairperson of the minimally invasive post-graduate course for the American College of Surgeons, Society of American Gastrointestinal Endoscopic Surgeons (SAGES), American Medical Association and Southern Medical Association. Dr. Rosser has written two books due to be released this fall, several chapters in major laparoscopic textbooks, and over forty surgical journal articles. His medical research interests are mini-laparoscopy under local anesthesia, conscious pain mapping, nerve injury syndromes, long-term central venous catheters, and continuous dynamic monitoring during endoscopic and laparoscopic procedures. Dr. Rosser has authored eight CD-ROM titles over the last five years, and six of them will be released next spring under the "Yale University Laparoscopic Series" label. His efforts have not only been directed toward surgeons, but have also broken new ground in the area of patient information and informed consent, gaining critical acclaim in both the *New England Journal of Medicine* and its European counterpart *The Lancet*.

As the founder of the non-profit organization Modern Day Miracle Incorporated, Dr. Rosser's goal is to expose the 'modern day miracle' of minimally invasive surgery to underprivileged and undereducated countries around the world, many times via telemedicine, the remote care of patients using modern telecommunications. His "Operation Outreach" pioneered the technique of remotely guiding surgeons with little or no experience, who ultimately performed successful advanced laparoscopic procedures with Dr. Rosser thousands of miles away, and he feels that the safe maturation of telemedicine should be an important aspect of 21st century healthcare. Modern Day Miracle Incorporated provides follow-up inspection, data gathering, and continuing education tours to countries in need, as well as here in the United States, thereby allowing the art form of laparoscopic surgery to be properly nurtured. The program has been implemented in Greece, Jamaica, Aruba, and other Caribbean countries. Dr. Rosser's research and development activities have been featured on the Learning Channel, the CBS Morning Show, CNN, and the Discovery Channel, and he has garnered three Smithsonian Awards.

SATAVA, Richard M, MD MS (Surg Rsch), FACS

Dr. Satava, MD, is a practicing general surgeon specializing in advanced medical technology research. He is also Professor of Surgery at Yale University School of Medicine. Dr. Satava is retired from the active duty Army Medical Corps and was previously the program manager at the Defense Advanced Research Projects Agency (DARPA). In addition to serving on the American College of Surgeons' Regents Committee on Informatics, Dr. Satava serves as a member of the College's Emerging Technologies and Residents Education Committees. He received his undergraduate degree at John Hopkins University, Baltimore, and he received his medical degree from Hahnemann University, Philadelphia. Dr. Satava served and internship at the Cleveland Clinic, his surgical residency at the Mayo Clinic, Rochester, MN and he completed a fellowship with a Masters of Surgical Research at the Mayo Clinic. He has been a member of the White House Office of Science and Technology Policy (OSTP), Committee on Health, Food and Safety. In addition, Dr. Satava is the past-president of the Society of American Gastrointestinal Endoscopic

Surgeons (SAGES), he is a member of the board of governors of the Society of Minimally Invasive Therapy, The Society of Laparoendoscopic Surgeons (SLS) and he is active in numerous surgical and engineering societies. Dr. Satava serves on the editorial board of numerous surgical and scientific journals and he has written extensively about surgical education and surgical research.

SINANAN, Mika N., MD FACS

Dr. Sinanan is currently an Associate Professor of Surgery and Adjunct Professor in Electrical Engineering at the University of Washington School of Medicine. He received his MD at the Johns Hopkins University School of Medicine and PhD in the Department of Physiology, University of British Columbia, Canada . He is the Co-Director of the Center for Videoendoscopic Surgery and Chief if Medical Staff at the University of Washington Medical Center. He is a dedicated researcher and frequent contributor to peer review publications in the area of minimally invasive surgery and surgical education.

The "Metrics Group" 10 July, 2001

First Row: Brian Clauser, Carleen Ellis, Sir Alfred Cuschieri, David Nahrwold, Ara Darzi, Patricia Youngblood, Jeffrey Hamdorf, Mika Sinanan, George Hanna, Gehard Buess. Second Row: Glenn Regehr, Ralph Clayman, Rick Satava, Paul Wetter, Randy Haluck, Leroy Heinrichs, Stephen Deane, Anthony Gallagher, Jack Jakimowicz, Vivek Datta. Third Row: Dan Smith, Butch Rosser, Adrian Park, Anthony DiSciullo, George Lewis. Fourth Row: Harvey Magee, Gerald Fried, Harry Hasson, Chris Kaufmann, Lee Sillin.